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Towards a European Research Area
Science, Technology and Innovation

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Towards a European Research Area
Science, Technology and Innovation

STRENGTHENING THE FOUNDATIONS OF THE EUROPEAN RESEARCH AREA
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The Directorate-General for Research initiates, develops and follows the Commission's political initiatives for the continued advancement of the European Research Area. It conceives and implements the necessary Community actions, in particular the Framework Programmes of the European Community for research, technological development and demonstration activities. It also contributes to the implementation of the revised Lisbon Strategy for Growth and Jobs.

Directorate M "Investment in Research and links with other policies" (Acting Director: Isi Saragossi) is responsible for the actions linked to the objective set at the European Summit of Barcelona in March 2002 of increasing Europe's overall level of investment in research so that it is approaching 3 % of GDP by 2010. The overall aim of these actions is to make Europe more attractive for investments in research and to increase the effectiveness of its research system by improving framework conditions and increasing the leverage effect of public spending on private R&D. This is achieved by enhancing the effectiveness and coherence of national and EU research policies and their articulation with other policies (competition, intellectual property rights, education, innovation etc...).

"Key Figures 2005" was prepared in Unit M02 "Open Co-ordination of Research Policies" of DG Research (Head of Unit: Xabier Goenaga) by Vincent Duchêne and Emmanuel Hassan, with the technical assistance of Dermot Lally. This Unit is responsible for the monitoring and assessment of national research policies in the context of the Lisbon Strategy. The Open Method of Coordination is applied to the 3 % objective by supporting mutual learning, peer review and concerted policy actions between Member States and regions. It also contributes to the identification of important issues with a strong trans-national dimension which could benefit from mutually reinforcing actions at national and EU levels. Unit M02 would like to acknowledge their gratitude to the many colleagues within Directorate M, DG Research and the other Commission services for their comments and suggestions on earlier drafts of this report.

URL: www.cordis.lu/indicators

Preface

The EU's top priority is to boost economic growth and to create jobs. This can only happen through far-reaching reforms to transform Europe into a dynamic knowledge economy, building on what Europe can do best – providing excellent education, undertaking excellent research, defining space for creativity and innovation. We live in a globalised economy in which Europeans cannot and should not compete with low wages, poor social conditions or unsustainable exploitation of the environment. Knowledge and innovation are thus primary factors for European competitiveness.

This transformation of Europe into a dynamic knowledge economy has been the objective of the so-called "Lisbon" agenda of structural reforms since 2000. In this framework, at the European Summit of Barcelona in March 2002, European Heads of State and Government set the goal of increasing Europe's overall level of investment in research to 3 % of GDP by 2010, and of raising the share of research funded by business.

The 2005 edition of the Key Figures offers for the first time official data on the evolution of R&D activities up to 2003, one year after the Barcelona commitment. The results are worrying: they do not match the political commitment of 2002. In fact most figures show that Europe is becoming less attractive for private R&D investment.

In 2003, business funding of R&D grew at a slower pace than GDP and public funding of R&D grew only slightly faster than GDP. As a result, the R&D intensity was almost stagnant at 1.93 % of EU-25 GDP in 2003, lagging well behind the United States with 2.6% and Japan with 3.2 %. If the current trend persists, EU R&D investment will reach only 2.2 % of GDP in 2010, well below the 3 % Barcelona objective.

At the same time, a number of emerging countries have been increasing their R&D expenditure at a very high pace – close to 20 % a year in China – notably thanks to increasing investments from European and American companies. Based on such trends, China is forecast to have caught up with the EU-25 before 2010 in terms of the share of GDP allocated to R&D. European companies are indicating that they invest in R&D in these emerging countries not only because of lower costs but also because of the combination of well-trained human resources and large dynamic markets for technology and high-tech products.

Europe must heed this wake-up call. If the current trends continue, Europe will lose its opportunity to become a leading global knowledge-based economy, but I am convinced that the situation can be reversed if we react quickly and strongly. Together we can make Europe into a dynamic knowledge economy, which will create growth and jobs and which will sustain our model of society.

Janez Potočnik

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Highlights

This report takes a detailed look at the most important aspects of EU investment and performance in the knowledge-based economy, where R&D plays a central role, as well as at the most recent progress made in this regard.

Part I of the publication charts recent progress towards the knowledge-based economy in the global macro-economic context. Part II reviews investment in R&D, human resources in science and technology, and higher education. Part III deals with the performance of the EU's research and innovation systems, examining indicators such as scientific publications and patents as well as high-tech trade, productivity and value added at the sector level.

The Knowledge-based Economy in the Global Macro-economic Context

Labour productivity in the EU: no longer catching-up?

After 50 years of catching up to the US level of productivity, Europe has been falling behind since the mid-1990s

From the early 1950s to the beginning of the 1970s, sharp labour productivity growth in Europe was associated with a catching-up process in terms of GDP per capita levels with the US. Then, the comparative growth performance of Europe vis-à-vis the US experienced two marked changes.

Firstly, the gap in terms of GDP per capita levels between the US and the EU did not narrow further after the mid 1970s while the catching-up in terms of labour productivity continued. GDP per capita in the EU remains at only 70 % of GDP per capita in the US, i.e. roughly the same relative level as 30 years ago. This relative constant gap in GDP per capita can mainly be explained by a slowdown in the growth of labour input in Europe reflecting an increased unemployment, a decline in employment rates and a fall in average working hours per capita since the 1970s.

Secondly, the catching-up in terms of labour productivity stopped in the mid-1990s. While the average annual growth of labour productivity per hour declined in Europe by a full percentage point from 2.5 % in the first half of the 1990s to 1.5 % over 1996-2003, productivity growth in the US rose by a similar amount to 2.4 % per year. This deterioration of labour productivity growth in Europe occurs at a time when labour input shows signs of improvement. From a growth accounting perspective, the EU's under-performance vis-à-vis the US in terms of labour productivity growth stems from a reduction in the contribution from capital deepening and a decline in multifactor productivity. This is a serious threat for the international competitiveness of business activities in Europe. An important part of the answer to that threat lies with Europe's ability to leverage science, technology and innovation to create higher productivity and economic growth with more and better jobs.

Harnessing the potential of the knowledge-based economy

Activating knowledge is crucial to the improvement of economic performance

Policies of macro-economic stability and convergence have delivered substantial results over recent years. However, even though macro-economic stability is necessary for sustainable and long-term economic growth, it is not sufficient. Economic growth is neither a by-product nor an automatic consequence of policies of fine-tuning macro-economic and financial balances. It is widely recognised that productivity gains, sustained economic growth and employment are largely determined by technological progress, innovation and human capital. These factors are in turn largely dependent on investments in knowledge (e.g. investments in education and R&D) and their outcomes.

Increasing investment in R&D and its efficiency

In the contexts of the ageing population and of sluggish economic growth, the 2000 Lisbon strategy to make Europe a competitive knowledge-based economy by 2010, and more specifically the Barcelona objectives agreed upon in 2002 to increase R&D investment in the EU to approach 3 % of GDP, are more critical than ever. The European Commission's action plan "Investing in Research" adopted in April 2003 advocates increasing both R&D investment and the efficiency with which new ideas are turned into new products, processes, services, and solutions, as well as creating an environment which makes it more attractive for firms to increase investment in R&D. These objectives and orientations were confirmed and strengthened in the review of the Lisbon strategy undertaken earlier this year.

Investment in the Knowledge-based Economy

Trends in overall investment in R&D

EU R&D intensity is close to stagnation, while China is catching up very rapidly

In 2003, R&D intensity in the EU amounted to 1.93 %, well below the US (2.59 %) and Japanese (3.15 %) intensities, but above China (1.31 %). The rate of growth of the EU's R&D intensity (+0.7 % per year between 2000 and 2003) is far from sufficient to reach the 3 % objective in 2010: if this trend remains unchanged, the EU's R&D intensity will be only about 2.20 % in 2010. On the contrary, China experienced a very strong growth in R&D intensity over recent years, with annual growth rates of around 10 % since 1997. If current trends for both China and the EU continue in the coming years, China will have caught up with the EU by 2010 in terms of the share of GDP allocated to R&D. Within the EU, Finland and Sweden ranked highest in terms of R&D intensity in 2003, both with R&D intensities well above 3 %. Moreover, in both countries R&D intensity has increased substantially in recent years. Denmark, Belgium and Austria had both R&D intensity and growth rates above the European average. Among the countries with the highest R&D expenditure, only the UK had a R&D intensity below the EU average. Together with France and Germany, it also experienced weak growth in R&D intensity between 1997 and 2003, especially after 2000. Most of the new Member States had relatively low R&D intensities in 2003, but were catching up rapidly with the rest of the EU countries. All the new Member States except Slovakia, Poland and Latvia had R&D intensity annual growth rates far above the EU-25 average between 1997 and 2003.

The contribution from the business sector to the financing of R&D remains low and has even decreased since 2000

The R&D intensity gap between Europe and its main competitors is almost entirely due to differences in the contributions from the business enterprise sector to the financing of R&D. In 2002, the business enterprise sector financed 55.6 % of domestic R&D expenditure in the EU, compared to 63.1 % in the US and 73.9 % in Japan. The share of R&D financed by the business enterprise sector grew at the rate of 1.2 % per year from 1997 to 2000, but decreased by 0.6 % per year between 2000 and 2003. The overall target of two-thirds of R&D expenditure financed by the business sector will not be reached by 2010 if current trends remain unchanged.

High R&D-intensive countries maintain high levels of government R&D financing

The role of government in the financing of R&D remains important as evidenced by the fact that the highest levels of business R&D funding go hand in hand in most cases with high levels of government funded R&D intensity, as in Sweden, Finland, Germany and the US. In low R&D intensive countries such as the new EU Member States, government funded R&D in relation to GDP remains higher than the intensity of business funded R&D.

Business sector R&D

Business sector R&D intensity remains low in spite of healthy growth in several Member States

Business R&D expenditure amounted to only 1.23 % of GDP in the EU compared to 1.78 % in the US and 2.36 % in Japan in 2003. In China, R&D expenditure by the business enterprise sector is still below the EU-average at 0.82 % (% of GDP), but it is already higher than in most new Member States, the southern European countries and Ireland. Furthermore, China's Business R&D intensity has been growing rapidly at 11 % per year over recent years. Business R&D is mainly funded by the business enterprise sector, but the contribution of that sector is much higher in the US and Japan than in Europe. It amounted to 98.1 % in Japan and 90.0 % in the US in 2003, compared to 82.0 % in the EU (year 2002). However, patterns of business R&D funding are changing. Direct government funding of business R&D declined significantly in the EU, Japan and the US between 1997 and 2003. This downward trend is mirrored by a rise in indirect support, in particular R&D tax incentives in many EU countries as well as in the US and Japan.

Europe benefits less from the increased globalisation of R&D than its main competitors. Over the years 1997-2002, R&D expenditure by EU companies in the US increased in real terms much faster than R&D expenditure by US firms in the EU (+54 % against +38 %). As a result, the net gain for the US increased by a factor of 5.4 between 1997 and 2002, from about 300 million in 1997 to almost 2 billion in 2002 (€2001 PPS). Furthermore, US outward R&D investment grew over recent years in all major regions of the globe, but growth has been fastest outside the EU-15, particularly in emerging countries such as China. As a result, the share of the EU-15 in total US outward R&D investment has been declining since the late 1990s, and these trends are expected to continue as long as new actors build up their science and technology infrastructures and open their markets to foreign entrants. These worrying recent developments call for political reaction since they reflect the relatively stronger attractiveness of the US research and innovation systems compared to the EU's, and the increasing attractiveness of new entrants into the globalised science and technology systems. Without strong reaction, Europe risks entering into a worrying vicious circle as the loss of high value-added R&D activities and jobs undermines further its capacity to retain such activities.

Europe is losing its attractiveness for international R&D investment

EU-based firms tend to invest less than US firms in R&D in the services sector and in high-tech manufacturing. In the US, nearly 40 % of all business R&D is performed in the services sector

Business R&D is more concentrated in the services sector and in high-tech manufacturing in the US than in the EU

whereas in the EU this share is only 15 %. This gap has increased considerably due to a much faster growth in the US than in the EU in recent years. However, further study remains necessary to assess the type of services concerned and to draw appropriate policy conclusions. The share of high-tech manufacturing industries in total manufacturing R&D is also lower in the EU (41.4 %) than in the US (44.3 %).

SMEs perform a large part of business R&D in the EU

Nearly a quarter of business R&D is performed by SMEs in the EU (22.4 %), a figure substantially higher than in the US (14.1 %) and Japan (7.0 %). The higher concentration of R&D expenditure in small and medium-sized companies should not be a problem if this supports company expansion. Empirical evidence, however, shows that it is more difficult for European SMEs than for US SMEs to grow into large companies.

High-tech venture capital investment is three times higher in the US and is better targeted at more mature projects generating higher profits

The availability of technology venture capital – a catalyst for the creation and expansion of R&D intensive SMEs – is still much lower in the EU compared to the US. In 2003, the US's total investment in venture capital in high-tech sectors, as % of GDP, was more than three times the amount invested in the EU. US early stage venture capital investment in the high-tech sectors was twice as high as in EU-25. At the expansion stage, it was five times the amount invested in EU-25 (as % of GDP). Furthermore, the average investment in a technology company was in 2003 about nine times larger in the US, and the rate of return of early stage venture capital investment was 30 to 50 times higher in the US. US venture capitalists appear to be more successful at concentrating their investment on more advanced projects/technologies that are generating higher profits. The main problem for Europe consists less of an underperforming venture capital industry (supply side) than of the level of development of projects prior to early stage financing (demand side).

Public sector R&D and its relationship with the business enterprise sector

R&D performed in the higher education sector is on the increase

R&D performed in the higher education sector is on the increase in Europe, Japan and the US. In 2003, higher education expenditure on R&D amounted to 0.44 % of GDP in the EU, well above its 1997 level of 0.38 %. Higher education expenditure on R&D is also much greater than government expenditure on R&D.

In the new Member States the government sector is performing an important part of R&D

In the old EU Member States most public expenditure on R&D is performed by the higher education sector, whereas in the new Member States (with the exceptions of Lithuania, Latvia and Estonia) a sizeable share of public R&D is performed in the government sector.

The business enterprise sector funds a higher proportion of public research in the EU than in the US or Japan

Firms are financing significant levels of public R&D in the EU. The contribution of the business sector to the financing of R&D in the higher education sector is higher in the EU (6.6 %) than in the US (4.5 %) and Japan (2.6 %). Similarly, the business sector funds government R&D in a greater proportion in the EU than in the US and Japan.

Human resources in science and technology

The pool of researchers is much smaller in the EU, especially in the business sector, and the ageing process is eroding the S&T labour force

In 2003, the number of researchers (in Full-Time Equivalents) per thousand labour force amounted to only 5.4 in the EU compared to 10.1 in Japan and 9.0 in the US. This overall deficit is mainly located in the business sector, which nevertheless accounts for the bulk of R&D performance. Whereas in the EU about 49.0 % of researchers were employed by the business sector in 2003, this share amounted to 67.9 % in Japan and 80.5 % in the US. In addition, the ageing of the highly-qualified S&T labour force is becoming a concern in many Member States. In 2003, 34.7 % of highly qualified S&T employees in the EU were in the 45-64 year old age group, compared to 30.8 % in the 25-34 age group. Therefore, it remains crucial to ensure a sufficient replacement rate of the S&T workforce, and to further expand it.

The supply of human resources is large, but the financial commitment to tertiary education remains low, and women are still under-represented

The EU is producing more S&E graduates than the US and Japan. In 2003, 24.2 % of all degrees awarded in the EU were in S&E fields of study, a slight decrease from 1998. The corresponding figures for Japan and the US were 23.1 % and 18.5 % respectively. Overall funding of tertiary education (both from public and private sources) as a percentage of GDP, however, is lower in the EU than in the US. Women are still under-represented among both researchers and S&E graduates. Their share in the total of researchers (in headcounts) was below 50 % in 2002 in nearly all EU Member States.

Moreover, in several EU Member States S&T careers lack attractiveness (demand side)

Making research careers more attractive is necessary to increase the inflow of S&E educated people into research positions and S&E occupations. Various Members States, however, while producing many-S&E graduates, retain relatively low levels of Scientists and Engineers in their active population, indicating that a non-negligible part of their human resources opts for a non-S&E career or for jobs outside the country. This is particularly true in the case of countries with relatively low R&D intensities and a weak contribution of the business sector to R&D funding. This underlines the importance of the structure of the demand side. While a large production of S&E graduates may benefit the economy overall, low R&D intensities result in few employment opportunities, emigration (brain drain) or out-of-field employment.

Performance of the Knowledge-based Economy

S&T output

The EU is the world leader in scientific output, but is failing to fully exploit its scientific base

In terms of both total number and world share of scientific publications, the EU maintains a comfortable lead. In 2003, its world share was 38.3 % (showing a slight decline compared to its level in 1997) whereas the US was responsible for 31.1 % of world scientific publication output. When relating publications to population, however, the US led with 809 scientific publications per million population, followed by Europe with 639, and Japan with 569. Within the EU, this ratio was particularly high in the Nordic countries. As regards technological output, the EU accounted for a lower world share of triadic patents than the US in 2000 (31.5 % against 34.3 % for the US). When standardised by population size, the picture is even bleaker. Japan has the highest number of triadic patents per million population (93) followed by the US (53) and the EU (31). In Europe, only Finland and Sweden can keep pace with Japan, whereas both Germany and the Netherlands outperform the US. In contrast, no less than 13 EU Member States were producing less than 5 triadic patents per million population in 2000.

The S&T knowledge bases are highly diversified in the EU

Scientific and technological output, as measured by scientific publications and patents, is more diversified in the EU than in either the US or Japan in terms of scientific disciplines and technological fields. This is a potentially rich resource for the medium and long term, but it also requires supplementary efforts to ensure that both public research and industrial R&D are not too fragmented. The degree of technological specialisation varies sharply among the EU countries and does not seem to depend on their levels of R&D effort. For example, some countries with low R&D expenditure – including the Czech Republic, Greece, Poland and Spain – exhibit a relatively high diversification compared to the available means. Such diversification at national level reinforces the need for European integration.

Industry, technology and competitiveness

Manufacturing exports from the EU are less technology-intensive than those from the US and Japan

The trade performance of high-tech industries reflects both the specialisation patterns of an economy and the competitiveness of its domestic high-tech industries in the global marketplace. In 2003, high-tech industries accounted for about 20 % of total EU manufacturing exports, whereas they accounted for more than 25 % of total manufacturing exports in Japan and the US. Moreover US high-tech industries account for more exports at world level than the EU (nearly 20 % against 16.7 % in 2002). Finally, while the US and Japan show a structural trade surplus in high-tech manufacturing industries, the EU is characterized by a structural trade deficit in these industries.

Most of the EU-US R&D gap stems from the combined effect of low R&D intensities and the sizes of the services sector and ICT manufacturing

The services sector produces more than three quarters of total output in the US and the EU. In 2002, the services sector share in total value added amounted to about 84.7 % in the US and 79.1 % in the EU compared to 80.8 % and 77.1 %, respectively, in 1997. The share of ICT-related manufacturing industries (i.e. radio, television, and communication equipment; office, accounting and computing machinery; medical precision and optical instruments) in manufacturing output is much bigger in the US than in the EU. In contrast to the US and Japan, the EU mainly shows a technological specialisation in traditional manufacturing industries such as transport related industries, and is under-specialised in ICT manufacturing industries. Furthermore, the services sector invests considerably more in R&D in the US (0.7 % of GDP) than in the EU (less than 0.2 % of GDP). Compared to the EU, the R&D performed by the manufacturing sector in the US is heavily concentrated in ICT manufacturing industries. As a result, most of the EU-US R&D gap stems from a less R&D intensive services sector, as well as, to a lesser extent, a smaller size and lower R&D intensity in the ICT manufacturing sector.

The productivity growth problem in the EU compared to the US is mainly located in the ICT-using services sector and to a lesser extent in the ICT-producing manufacturing industries

Similarly, most of the productivity growth differentials between the US and the EU since the mid-1990s stem from the New Economy. In particular, the ICT-using services sector – especially distribution and financial services – has dramatically contributed to boost productivity growth in the US over those years, while its contribution in the EU has been much more limited. As regards the ICT-producing manufacturing sector, its contribution to overall productivity growth in the US and the EU has been much more modest because of its reduced share in aggregate value added. Consequently, a large ICT-producing sector does not seem to be a prerequisite to obtain the full benefits of ICT. Moreover, ICT alone is not sufficient to elevate productivity growth because ICT use requires complementary investments, in particular investment in intangible assets (e.g. skills, new work practices), and adequate framework conditions (e.g. product market regulation).

Part I – The Knowledge-based Economy in the Global Macro-economic Context

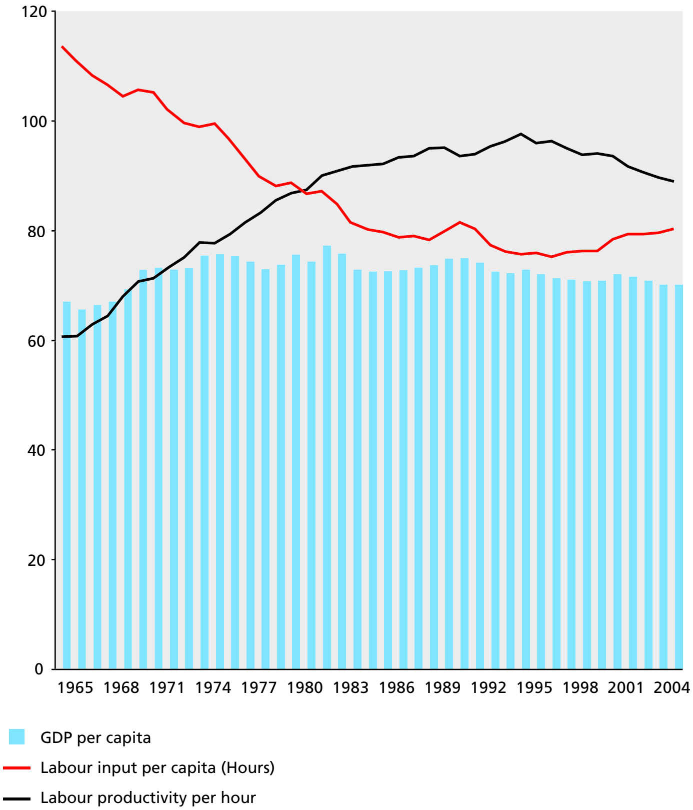
I-1. Labour productivity growth in Europe: no longer catching-up?

Throughout the years from the early 1950s to the beginning of the 1970s, sharp labour productivity growth in Europe was associated with a catching-up process in terms of GDP per capita levels with the US. Then, the comparative growth performance of Europe vis-à-vis the US experienced two marked changes.

Firstly, the gap in terms of GDP per capita levels between the US and the EU did not narrow further after the mid 1970s while the catching-up in terms of labour productivity continued. GDP per capita in the EU remains at only 70 % of GDP per capita in the US, i.e. roughly the same relative level as 30 years ago. This relative constant gap in GDP per capita can mainly be explained by a slowdown in the growth of labour input in Europe reflecting an increased unemployment, a decline in employment rates and a fall in average working hours per capita since the 1970s.

Secondly, the catching-up in terms of labour productivity came to an end in the mid-1990s with the EU's labour productivity growth rate falling below that of the US. While the average growth of labour productivity per hour in Europe amounted to around 2.5 % per year in the first half of the 1990s, well above the US growth rate, it then declined by a full percentage point to 1.5 % over 1996-2003,

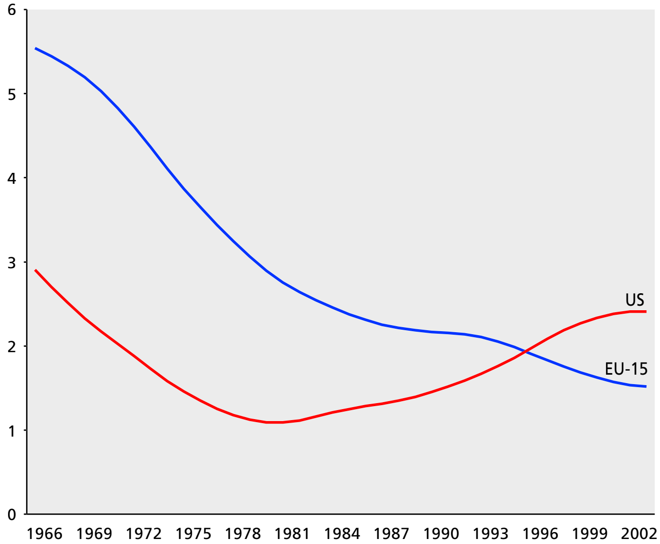
Figure I.1.1 GDP per capita levels accounting - EU-15 relative to the US (US=100) (proportion of income differences due to labour utilisation/productivity)



Source: DG ECFIN
Key Figures 2005
Data: DG ECFIN (AMECO database)

compared with an increase of an approximately similar amount in the US to 2.4 %. This deterioration of labour productivity growth in Europe occurs at a time when labour input shows signs of improvement.

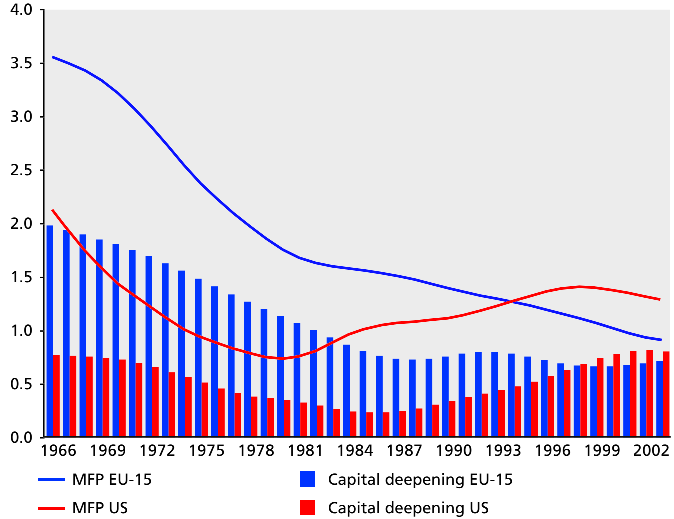
Figure I.1.2 Labour productivity per hour growth trends (percentage change from previous year)



Source: DG ECFIN Key Figures 2005
Data: DG ECFIN (AMECO database)

From a growth accounting perspective, the EU's under-performance vis-à-vis the US in terms of labour productivity growth stems from both a reduction in the contribution from capital deepening and a decline in multifactor productivity. The latter may partially reflect an EU under-performance in the creation, diffusion, and utilization of new knowledge over recent years[1].

Figure I.1.3 Decomposition of US and EU-15 labour productivity growth trends into capital deepening and multifactor productivity (in percentage points)



Source: Denis, McMorrow, Röger and Veugelers (2005). Key Figures 2005
Data: DG ECFIN (AMECO database)

1. It is important to note that multifactor productivity growth is not necessarily caused by technological change. Indeed, other factors can impact on multifactor productivity growth. These factors include adjustment costs, economies of scale, cyclical effects, changes in efficiency (e.g. organisational change) and measurement errors.

I-2. Harnessing the potential of the knowledge-based economy

Knowledge is a key engine for productivity and long-term economic growth

Against this background, and despite the fact that the EU's main competitors were generally hit by the same economic slowdown after 2000, the aforementioned developments show that the EU is no longer catching-up and is not meeting the Lisbon targets as highlighted in the 2004 Kok report[2]. Economic performance is determined by a variety of macroeconomic policies and structural conditions and thus differs significantly across regions and countries. For instance, stability-oriented macroeconomic policies (e.g. inflation, fiscal policy), trade policy, financial market conditions and labour market institutions have a substantial impact on economic performance. However, in the long run, the economic performance of countries is strongly determined by knowledge-related factors (e.g. technical change, human capital). In particular, R&D and technological innovation have contributed substantially to the strong US economic performance over recent years[3]. More generally, the contribution of knowledge investments and activities to employment, productivity and economic growth has been emphasised in many studies.

Box 1. The links between knowledge and economic performance: results from some quantitative studies

A quantitative analysis undertaken by the Erasme team for the EC on the expected macro-economics benefits from an increase in R&D intensity in Europe shows that if R&D investment reaches 3 % of GDP in 2010, the European economy will experience by 2015 a rise in the number of jobs of 3.1 million and an additional boost to GDP of 4.2 %[4].

The 2004 European Competitiveness Report[5] shows that in the OECD area increasing R&D expenditure in the higher education and business sectors has a significant positive impact on GDP per capita growth. The results are more mitigated concerning the impact of R&D expenditure in the government sector.

A recent empirical OECD study[6] points to the positive impacts of increases in human capital (as measured by average number of years in education), suggesting high returns on investment in education. The results of this study also point to a marked positive effect on business-sector R&D.

According to the EU Economic Review[7], a substantial increase in knowledge investment (R&D and education) could boost potential EU growth rates by between one half and three quarters of a percentage point annually over a 5-10 years horizon. Regarding the US, the knowledge-based economy appears to be more fully entrenched, with studies suggesting that investments in R&D and education can explain almost as much as 75 % of the US productivity growth rate over the period 1950-2003. The differences in EU-US productivity patterns are fundamentally driven by the superiority of the US in terms of its capacity to produce and absorb new technologies.

2. Kok W. (2004), Facing the Challenge: The Lisbon strategy for growth and employment, Report from the High Level Group chaired by Wim Kok, November 2004.
3. European Commission (2004), EU Economy Review 2004, Brussels.
4. Zagamé, P. (2004), 3 % d'effort de R&D en Europe en 2010: analyse des conséquences à l'aide du modèle Némésis, January 2004, Report to DG RTD.
5. European Commission (2004), The European Competitiveness Report 2004, Brussels.
6. OECD (2003), The Sources of Economic Growth, OECD, Paris.
7. European Commission (2004), EU Economy Review 2004, Brussels.

In this context, the 2000 Lisbon strategy and more specifically the Barcelona objective set up in 2002 are more critical than ever for Europe. It is essential that knowledge is fully recognised as a key engine for productivity and sustained economic growth and that the transition of the EU economies towards a knowledge driven economy, within which education and training, R&D and innovation, and ICTs play a critical role, is speeded up. In particular, it is necessary to increase the efficiency of R&D, improve the transformation of new ideas into new products, processes, services and solutions, and make the overall environment more supportive of firms wanting to increase investment in R&D. In this respect, the European Commission's action plan "Investing in Research" adopted in April 2003 proposed a set of actions to boost public and private R&D efforts in order to approach R&D intensity (i.e. R&D expenditure-to-GDP ratio) of 3 % by 2010.

Box 2. The composite indicators on the knowledge-based economy

Composite indicators, by aggregating a number of key variables, attempt to summarise into one single measure various aspects of complex, multidimensional phenomena such as the transition to the knowledge-based economy. Two composite indicators have been developed: a first one summarises the various forms of investment in the knowledge based economy, whereas the second one measures the overall performance in the transition to the knowledge-based economy.

In order to advance effectively towards the knowledge-based economy, countries need to invest in both the creation and the diffusion of new knowledge. The composite indicator of investment in the knowledge-based economy addresses these two crucial dimensions of investment. It includes key indicators such as R&D expenditure, investment in human resources, and expenditure for the purchase of new capital equipment that may contain new technology (see table below).

Component indicators for the composite indicator of investment in the knowledge-based economy

Sub-indicators	Type of knowledge indicator
Total R&D expenditure per capita	Knowledge creation
Number of researchers per capita	Knowledge creation
New S&T PhDs per capita	Knowledge creation
Total Education expenditure per capita	Knowledge creation and diffusion
Life-long learning	Knowledge diffusion: human capital
E-government	Knowledge diffusion: information infrastructure
Gross fixed capital formation (excluding construction)	Knowledge diffusion: new embedded technology

Investment in the knowledge-based economy is, however, only part of the story. In particular, investment also needs to be allocated in the most effective way in order to increase productivity and economic growth. The second composite indicator regroups the four most important elements of the performance in the knowledge-based economy: overall labour productivity, scientific and technological output, usage of the information infrastructure and effectiveness of the education system.

Component indicators for the composite indicator of performance in the knowledge-based economy

Sub-indicators	Type of knowledge indicator
GDP per hour worked	Productivity
European and US patents per capita	S&T performance
Scientific publications per capita	S&T performance
E-commerce	Output of the information infrastructure
Schooling success rate	Effectiveness of the education system

The results of the composite indicators presented here refer only to the EU-15 Member States.

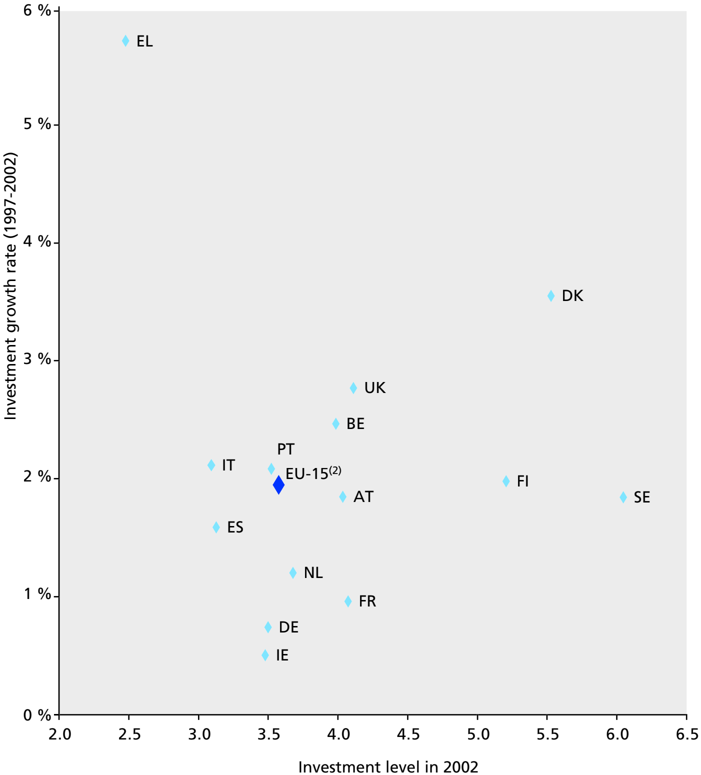
Speeding up the transition to a knowledge-based economy has admittedly been an important objective of European policies during recent years, especially after the European Council of Lisbon in March 2000. This objective has been reaffirmed in the revised Lisbon strategy in 2005[8]. An assessment is made below of the progress towards this important target using two "composite indicators". These indicators focus on the 'knowledge dimension' of this transition and, therefore, do not take into account the other dimensions (e.g. employment, sustainable development, etc.) of the Lisbon Agenda.

Investment in the knowledge-based economy varies greatly across Member States. The Nordic countries are characterised by a level of investment which is far beyond that of the EU-15 average and by growth rates close to or above the average. These countries are well prepared and are rapidly transforming their economies into knowledge-based economies. The UK, Belgium and Austria show an investment level ahead of the EU-15 average and growth rates close to or above the average. The southern countries are lagging behind, although Portugal has almost reached the average investment level. Spain, in particular, is not catching up with the rest of Europe. Greece is catching up very rapidly. Finally, a last group consisting of Germany, Ireland, the Netherlands and France is close to or slightly ahead of the EU-15 average in terms of investment level but is losing momentum with low investment growth rates over the past five years.

Countries that invest heavily in the knowledge-based economy, such as the Nordic countries, perform better than other countries. Conversely, countries with low levels of investment, such as the southern European countries, exhibit weaker performance levels. A closer analysis shows nevertheless that there exists substantial variation in the way investment is being translated into performance. Portugal and Germany have comparable levels of investment in knowledge, but differ widely from each other in terms of performance. On the other hand, countries such as Austria and Denmark have identical performance levels although the level of investment is much lower in Austria.

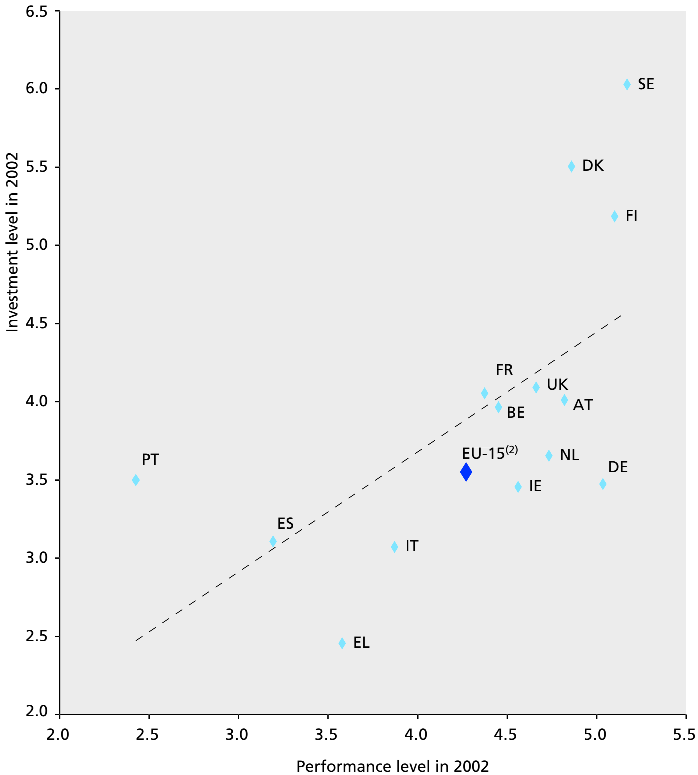
8. European Commission (2005), Working together for growth and jobs: Next steps in implementing the revised Lisbon strategy, (Commission Staff Working Document SEC(2005) 622/2).

Figure I.2.1 Composite indicator of investment in the knowledge-based economy - relative country positions in 2002 and annual growth rate 1997-2002[1]



Source: DG Research Key Figures 2005
Data: Eurostat, OECD, DG Information Society
Notes: (1) For the composition of the composite indicators, see Box 2.
(2) EU-15 does not include LU.

Figure I.2.2 Investment vs Performance in the knowledge-based economy - relative country positions in 2002[1]



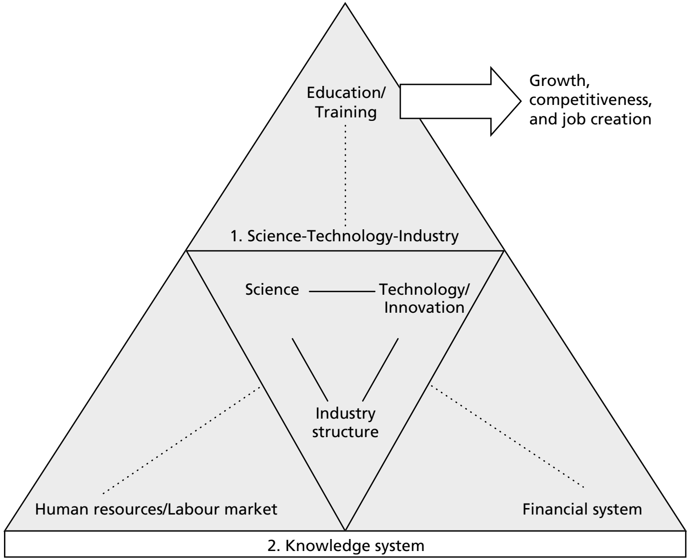
Source: DG Research Key Figures 2005
Data: Eurostat, OECD, DG Information Society
Notes: (1) For the composition of the composite indicators, see Box 2.
(2) EU-15 does not include LU.

From knowledge to the "knowledge system"

These examples show that the relationship between investment in knowledge and performance is complex and non-linear. What factors can explain the differences in innovative performance across countries? An important source of diversity between industrialized economies relates to the respective roles of the main actors (i.e. firms, universities, and government and other public research institutions) in the process of knowledge production, diffusion and utilisation as well as to the forms, quality, and intensity of their interactions. These actors are influenced by a variety of factors that exhibit some degree of country specificity such as the industry structure, the education and training system, the human resources and the labour market, the financial system, etc. State intervention should also be emphasized as it plays a horizontal role with regard to the influence of the other institutions involved in the "knowledge system". From this perspective, it covers infrastructure, the education system, legislation (e.g. IPRs, anti-trust policy, labour market), and broadly speaking corrective measures for market failures and policies aiming at ensuring macro-economic stability.

By examining all the different institutions in a country which jointly and individually contribute to the production, diffusion and utilisation of knowledge, it is possible to identify the main building blocks of a 'knowledge system'. In this system, science, technology/innovation and industry are central but not sufficient to ensure economic growth, competitiveness and job creation. The education and training system, human resources and the labour market, and the financial system all have a substantial impact on the performance of 'Science-Technology-Industry'. From this perspective, the performance of an economy depends not only on how the individual institutions perform in isolation, but also on how they interact with each other as elements of a collective system of knowledge creation, diffusion and use, and on their interplay with other institutions. Such interactions between various policies and above all the need for better coherence between them are stressed in the recent 'Integrated Guidelines for Growth and Jobs (2005-2008)' dealing with macro-economic, micro-economic and employment issues and proposed by the European Commission in the framework of the revised Lisbon strategy[9].

Figure I.2.3 The 'Knowledge System', its various constituting blocks and the interrelations between them.



Source: Adapted from Boyer R., Amable B. and Barré R., Les systèmes d'innovation à l'ère de la globalisation, Economica, 1999. Key Figures 2005

9. European Commission, Integrated Guidelines for Growth and Jobs (2005-2008), COM(2005)141.

Box 3. The New Integrated Guidelines for Growth and Jobs (2005-2008)

On March 22 and 23, 2005, the Heads of State and Government of the EU endorsed the revision of the Lisbon Strategy as proposed by the Commission. The Spring European Council approved the simplified governance arrangement with one set of Integrated Guidelines dealing with macro-economic, micro-economic and employment issues. Taking stock of the unsatisfactory results half way to the 2010 target, the Commission proposed a fundamental revision of the original strategy. To overcome the rather limited implementation of reform in Member States so far, the Commission has proposed focusing partnership with Member States on growth and jobs and introduced a Lisbon Action Plan that outlines actions to be taken at EU and at national level under three policy areas:

Making Europe a more attractive place to invest and work

(1) Extend and deepen the internal market
(2) Ensure open and competitive markets inside and outside Europe
(3) Improve European and national regulation
(4) Expand and improve European infrastructure

Knowledge and innovation for growth

(5) Increase and improve investment in Research and Development
(6) Facilitate innovation, the uptake of ICT and the sustainable use of resources
(7) Contribute to a strong European industrial base

Creating more and better jobs

(8) Attract more people into employment, increase labour supply and modernise social protection systems
(9) Improve the adaptability of workers and enterprises
(10) Invest more in human capital through better education and skills.

The Commission proposal for the integrated guidelines package is mainly based on the priority action areas as identified in its Lisbon mid-term review. While the macro-economic guidelines (covering for instance budgetary policy, reduction of public debts and EMU issues) have no counterpart in the Lisbon Action Programme, the micro-economic guidelines build on Lisbon action areas (1) to (7), and the employment guidelines build on Lisbon action areas (8) to (10).

Modernising economic and employment coordination in the EU will help deliver on the new Lisbon objectives to create growth and jobs. The proposed Integrated Guidelines will constitute the beginning of a new governance cycle. On the basis of the guidelines, Member States will draw up three-year national reform programmes. Member States will report each autumn on the implementation of the reform programmes in a single national Lisbon report. The Commission will analyse and summarise these reports in an EU Annual Progress Report in January of each year. On the basis of the progress report, the Commission can propose amendments to the integrated guidelines, if necessary.

Because national systems have developed at different times and under different conditions, the characteristics of the 'knowledge system' of a country are often rather specific. These disparities between 'knowledge systems' are in part a product of history and a legitimate expression of national preferences. However, it is crucial that unnecessary disparities do not hamper the development of integrated markets for research, technology and high-tech products towards a true 'European Area of Knowledge'. Business investment decisions are primarily determined by the size and dynamism of these markets, which are thus becoming a crucial factor of attractiveness in the global economy.

The rest of this report takes a detailed look at the most important aspects of EU investment and performance in the knowledge-based economy. Part II of the publication presents indicators of investment in R&D, human resources in science and technology and higher education, which are key components of the 'knowledge system'. Part III deals with the performance of the EU's research and innovation systems, presenting indicators such as scientific publications and patents, as well as high-tech trade, productivity and value added at the sector level.

Part II – Investment in the Knowledge-based Economy

II-1. Introduction

Interest in the contribution of R&D and human capital to the creation and growth of a knowledge-based economy has reached new heights in the EU in recent years. Today, it is widely agreed that research and technological advancement together with the availability of a highly skilled workforce are among the key factors for innovation, competitiveness and socio-economic welfare. Likewise, the capacity to exploit knowledge has become a crucial element for the production of goods and services.

Relevant statistical data and analysis are presented below. Firstly, investment in research and R&D expenditure by the main sources of funding are analysed. Secondly, since in most countries the business sector plays a major role in the financing and performance of R&D, private investment is looked at in more detail. Trends in venture capital investment are also examined. Thirdly, key indicators on human resources for science and technology, such as the number of researchers and education data are analysed. The analysis covers all EU-25 Member States, the US and Japan.

II-2. Trends in overall investment in R&D

This section examines the latest developments in R&D investment. It provides an overall picture of the level of commitment to the creation of new knowledge and to the exploitation of research results in different countries. The volume of R&D investment is a proxy for countries' innovation capacity, and reflects the magnitude of both the accumulation and the application of new knowledge. The R&D intensity indicator compares countries' R&D expenditure with their GDP. It also facilitates comparisons of the R&D activities between countries. R&D expenditure broken down by main sources of funds reveals information on the structure of financing and the relative importance of the various sources in different national R&D systems.

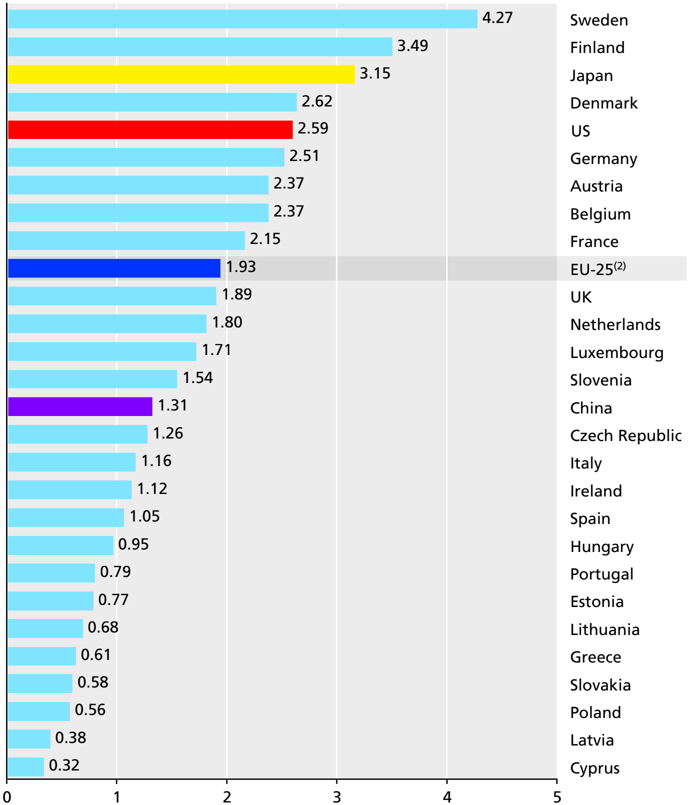
EU R&D intensity is close to stagnation, while China is catching up very rapidly

In 2003, EU R&D intensity was 1.93 %, well below the US (2.59 %) and Japan (3.15 %), but above China (1.31 %). Finland and Sweden ranked highest in terms of R&D intensity. They were the only two EU Member States in which R&D intensity exceeded 3 %. Denmark, Germany, Austria, Belgium and France also had R&D intensities significantly above the European average. Among the countries with the highest R&D expenditures, i.e. Germany, France and the UK (representing about two-thirds of the total R&D investment in the EU-25), only the UK had an R&D intensity below the EU average. Most of the new Member States had relatively low R&D intensities, with only Slovenia and the Czech Republic exceeding 1 %.

Some conclusions can be drawn concerning the rate of progress towards the 3 % objective over recent years. At EU-25 level, the rate of growth of R&D intensity did not significantly decrease after 2000. However, an annual growth rate of 0.7 % (average annual growth between 2000 and 2003) is far from sufficient to reach the 3 % objective by 2010. If this trend remains unchanged, the EU's R&D intensity will be only about 2.20 % in 2010[10].

10. Linear forecast on years 2000-2003.

Figure II.2.1 R&D intensity (GERD as % of GDP), 2003(1)



Source: DG Research
Key Figures 2005
Data: Eurostat, OECD
Notes: (1) LU: 2000; SE: 2001; IE, IT, NL: 2002; BE: 2004; AT: 2005.
(2) EU-25 was estimated by DG Research and does not include LU and MT.

Table II.2.1 Gross domestic expenditure on R&D (GERD), 2003(1) and average annual real growth (%), 2000-2003(2)

	GERD	
	Total mio euro	Average annual real growth %
Belgium	*6713*(5)	5.3
Czech Republic	1013	3.5
Denmark	*4907*	5.8
Germany	54310	1.2
Estonia	*62*	16.7
Greece	943	1.5
Spain	8213	6.7
France	*34122*	1.4
Ireland	1436	5.2
Italy	14600	5.2
Cyprus	*38*	12.4
Latvia	38	1.8
Lithuania	*110*	12.4
Luxembourg	364	:
Hungary	693	9.7
Malta	:	:
Netherlands	8018	-1.6
Austria	*5774*	5.7
Poland	1036	-3.5
Portugal	*1033*	-0.1
Slovenia	*377*	5.0
Slovakia	169	0.6
Finland	5005	2.8
Sweden	10459	11.0
UK	30085	2.6
EU-25(3)	*189584*	2.4
US(4)	*251577*	0.4
Japan	119748	2.2
China	16435	18.6

Source: DG Research
Key Figures 2005
Data: Eurostat, OECD
Notes: (1) LU : 2000; SE : 2001; IE, IT, NL : 2002; BE : 2004; AT : 2005.
(2) SE : 1999-2001; EE, IE, IT, NL : 2000-2002; BE : 2000-2004; AT : 2000-2005; EL : 2001-2003.
(3) EU-25 was estimated by DG Research and does not include LU and MT.
(4) US does not include most or all capital expenditure.
(5) Values in *italics* are provisional.

On the contrary, China experienced a very strong growth of its R&D intensity since the end of the 1990s, with annual growth rates above 10 % (total R&D expenditure grew, in real terms, by almost one fifth each year). In this regard, China is growing faster than any other economy in the Triad. If current trends for both China and the EU continue in the coming years, China will have caught up with the EU by 2010 in terms of GDP allocated to R&D. The EU's R&D intensity, however, grew at a higher rate than that of the US. As a result, the EU as a whole has been catching up with the US since 2000. The growth of R&D intensity is higher in Japan than in both the EU and the US, although this seemingly good performance can be partially explained by the low growth rate of Japan's GDP (denominator) over recent years.

An examination of the individual Member States and their pace of progress before and after 2000, reveals a distinction between five groups of EU countries.

A first group consisting of the new Member States Cyprus, Estonia, Hungary, Lithuania and the two southern countries Italy and Spain was able to accelerate its catching up process with the EU average after 2000. The R&D intensity in these countries remains low, but its rate of growth is above average and has been increasing.

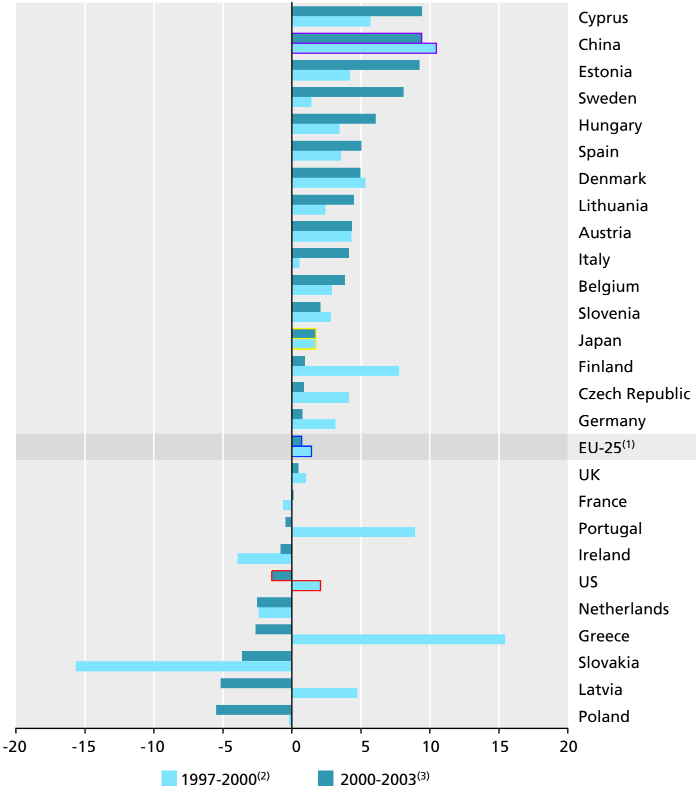
Slovenia, the Czech Republic, Latvia, Portugal and Greece represent a second group of low R&D intensive countries. Up to 2000, R&D intensity in these countries was increasing much faster than average. Their catching-up process, however, has slowed (Slovenia) or has even come to an end (Czech Republic, Latvia, Portugal and Greece) after 2000.

A third cluster consisting of the low R&D intensive countries Poland, Slovakia and Ireland is falling further behind. This group is not catching up with the rest of Europe. Furthermore, R&D intensity in these countries has been decreasing since 2000.

Amongst the countries with average to high R&D intensities, Sweden, Belgium and Austria, were able to sustain (Austria), slightly accelerate (Belgium) or strongly accelerate (Sweden) their rate of growth after 2000. These countries are pulling further ahead.

On the contrary, the other high R&D intensive countries Finland, Denmark, Germany and the UK are slowing down their pace of progress. Finland, and to a lesser extent Germany, experienced a significant deceleration of R&D intensity growth, down since 2000 to a level very close to the EU average. For Denmark the slowdown is negligible and R&D intensity is still growing at a much higher pace than average. Finally, while France's decline stopped after 2000, the Netherlands continues on its negative path.

Figure II.2.2 R&D intensity (GERD as % of GDP) - average annual growth (%)



Source: DG Research Key Figures 2005

Data: Eurostat, OECD

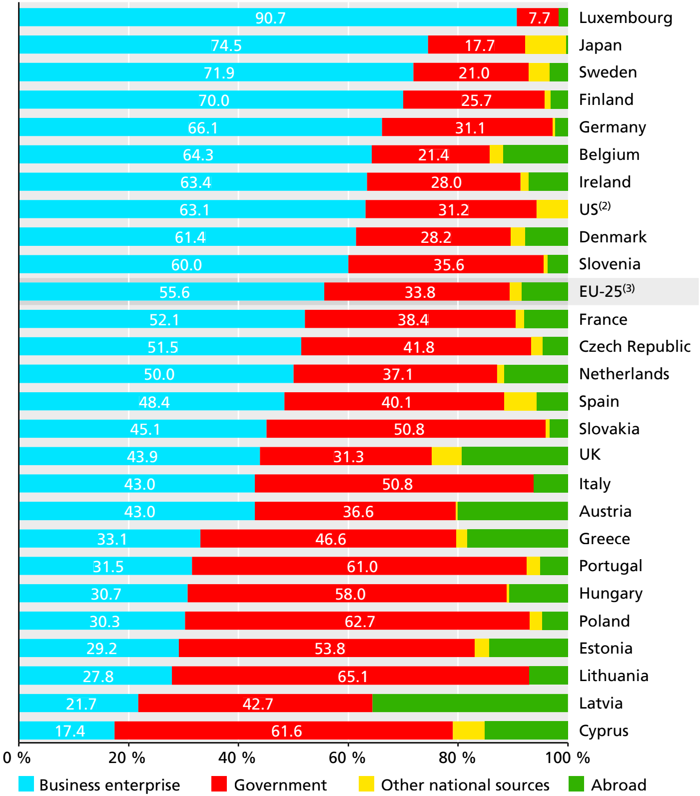
Notes: (1) EU-25 was estimated by DG Research and does not include LU and MT.
(2) EL, FR, SE, CN: 1997-1999; EE, CY, US: 1998-2000.
(3) SE: 1999-2001; EE, IE, IT, NL: 2000-2002; BE: 2000-2004; AT: 2000-2005; EL: 2001-2003.

The contribution from the business sector to the financing of R&D remains too limited and has even decreased since 2000

The business enterprise sector constitutes the most important source of funding of domestic R&D in the EU. In spite of increases since 1997, however, its role remains less significant than in the US and Japan. In 2002, the share of R&D financed by the business sector amounted to 55.6 % in Europe, compared to 63.1 % in the US and 73.9 % in Japan. Within the EU, Luxembourg, Sweden, Finland and Germany ranked highest in terms of the share of R&D expenditure funded by the business sector. Conversely, the government sector is still a large source of R&D funding in low R&D-intensive countries such as the southern European countries and the new Member States. In 2002, Cyprus, Lithuania, Poland and Portugal received more than 60 % of their R&D funding from the government sector.

A particular source of concern is the fact that the contribution of the business sector to the funding of R&D in the EU is decreasing since 2000. After modest growth in the late 1990s, the share of the business enterprise sector in the funding of total R&D has decreased by 0.6 % per year between 2000 and 2002.

Figure II.2.3 R&D expenditure by main sources of funds (%), 2002(1)



Source: DG Research Key Figures 2005
Data: Eurostat, OECD
Notes: (1) IT : 1996; LU : 2000; BE, DK, EL, PT, SE : 2001; CZ, DE, ES, HU, PL, SK, FI, UK, US, JP : 2003; AT : 2005.
(2) US does not include most or all capital expenditure.
(3) EU-25 was estimated by DG Research and does not include LU and MT.

Box 4. Institutional classification of R&D

Research and experimental development (R&D) comprise creative work undertaken on a systematic basis in order to increase the stock of knowledge, including knowledge of man, culture and society, and the use of this stock of knowledge to devise new applications.

R&D data are compiled in accordance with the guidelines laid down in the Proposed standard practice for surveys of research and experimental development — Frascati Manual, OECD, 2002. R&D expenditure is broken down by the following sectors of performance: business enterprise (BES), government (GOV), higher education (HES) and private non-profit (PNP). It is further broken down into five sources of funds: BES, GOV, HES, PNP and abroad.

The business enterprise sector (BES) includes all firms, organisations and institutions whose primary activity is the market production of goods or services (other than higher education) for sale to the general public at an economically significant price.

The government sector is composed of all departments, offices and other bodies which furnish, but normally do not sell to the community, those common services, other than higher education, which cannot otherwise be conveniently and economically provided, as well as those that administer the state and the economic and social policy of the community. (Public enterprises are included in the business enterprise sector.)

The private non-profit sector includes non-market, private non-profit institutions serving households (i.e. the general public), private individuals or households.

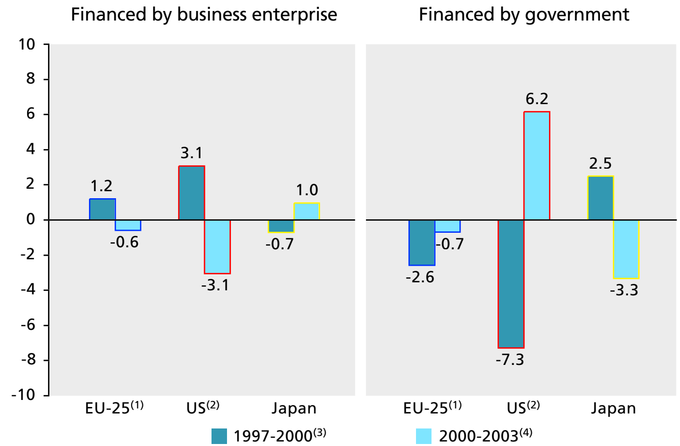
The higher education sector consists of all universities, colleges of technology and other institutions of post-secondary education, whatever their source of finance or legal status. It also includes all research institutes, experimental stations and clinics operating under the direct control of or administered by or associated with higher education institutions.

The sector abroad includes all institutions and individuals located outside the political borders of a country, except vehicles, ships, aircraft and space satellites operated by domestic entities and testing grounds acquired by such entities. It includes also all international organisations (except business enterprises), including facilities and operations within the country's borders.

In recent years, the contributions of business sector versus government to the financing of R&D have evolved in the same way in both the EU and the US. In both regions the contribution from the business sector first increased between 1997 and 2000 and then was reduced after 2000, whereas the government contribution followed almost the opposite pattern. The significant difference between the EU and the US here comes from the magnitude of movements: the redistribution of the funding roles in the US is much more cyclical than in the EU. During the period of economic downturn, there was in the US a much sharper reduction of the private contribution than in the EU, which in turn was compensated by a larger increase of governmental involvement compared to the EU.

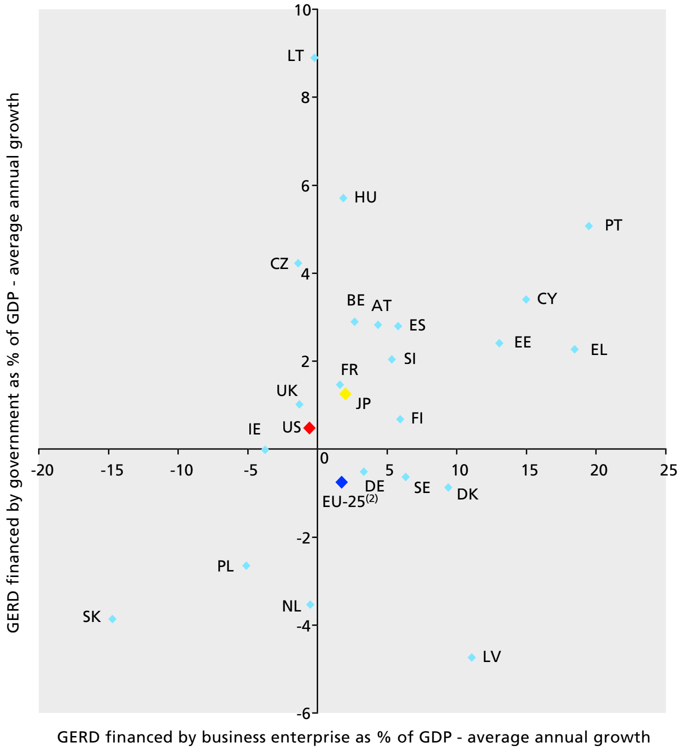
In most of the EU countries, rising R&D intensity has largely been driven by increased funding from the business sector. This is particularly true for the rapidly catching-up countries such as Portugal, Greece, Estonia and Cyprus. In contrast, in Lithuania, Hungary and the Czech Republic, the rapid catching-up process has mainly been caused by an increase in government contributions. The low and declining R&D intensities of Poland and Slovakia were caused by decreases in the contributions from both the business and the government sectors. For the countries with established high R&D intensities, growth was exclusively driven by the business sector (Denmark, Sweden, Germany), whereas in Belgium, Austria, Spain, Slovenia, France and Finland, government-funding also played an important role.

Figure II.2.4 Share of GERD financed by business enterprise and by government - average annual growth (%)



Source: DG Research Key Figures 2005
Data: Eurostat, OECD
Notes: (1) EU-25 was estimated by DG Research and does not include IT, LU and MT.
(2) US : Most or all capital expenditure is not included.
(3) US : 1998-2000.
(4) EU-25 : 2000-2002.

Figure II.2.5 GERD financed by business enterprise and by government as % of GDP - average annual growth, 1997-2002(1)



Source: DG Research Key Figures 2005

Data: Eurostat, OECD

Notes: (1) BE, DK, EL, PT, SE : 1997-2001; DE, ES, HU, PL, SK, UK, JP : 1997-2003; AT : 1997-2005; EE, CY : 1998-2002; CZ, FI, US : 1998-2003; FR, LT : 2000-2002.

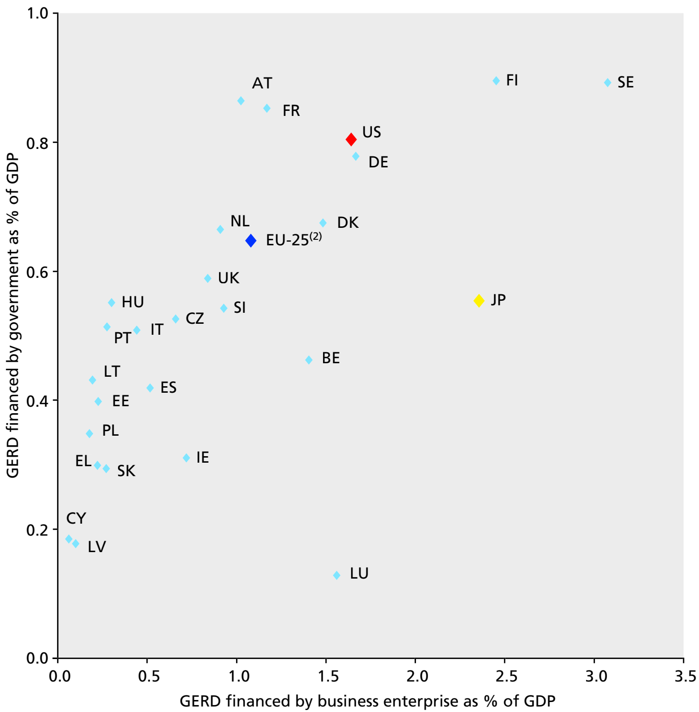
(2) EU-25 was estimated by DG Research and does not include IT, LU and MT.

High R&D-intensive countries maintain relatively high levels of government-funded R&D

Domestic R&D efforts are largely financed by business sector R&D in the US, Japan and Europe, while governments are playing a smaller role. Although the R&D intensity gap between Europe and its main competitors is almost entirely due to differences in business financed R&D, the role of government in the financing of R&D should not be underestimated.

The level of government funded R&D is still substantial in many high R&D intensive countries such as the three Nordic countries, Germany, France and the US, a sign also that high private involvement in the funding of R&D does not preclude government funding. Moreover, in low R&D intensive countries such as the new EU Member States, government funded R&D in relation to GDP is higher than the level of business funded R&D. Government funding of R&D is critical for creating and developing research infrastructures, carrying out mission-oriented research (e.g. defence, energy, public health, etc.) and for supporting research projects with high expected social benefits, which the business sector would not find sufficiently attractive.

Figure II.2.6 GERD financed by business enterprise and by government as % of GDP, 2002(1)



Source: DG Research Key Figures 2005
Data: Eurostat, OECD
Notes: (1) IT : 1996; LU : 2000; BE, DK, EL, PT, SE : 2001; CZ, DE, ES, HU, PL, SK, FI, UK, US, JP : 2003; AT : 2005.
(2) EU-25 was estimated by DG Research and does not include LU and MT.

II-3. Business sector R&D

The level and intensity of overall expenditure on R&D are key determinants of the future competitiveness of an economy. But it is also important to look at the sectors in which R&D is performed. The business sector is probably the most important in this regard. It is closest to consumers and best positioned to significantly improve or develop new products based upon new combinations of existing knowledge or knowledge newly developed through research in-house or elsewhere and to exploit this commercially. Business R&D expenditure is market-driven and accounts for an important share of innovation expenditure. In a direct way and through stimulating other sectors, this in turn leads to employment and economic growth. The level and intensity of business R&D expenditure, as well as the structure of its funding, is therefore a key determinant of an economy's future competitiveness, and a key concern for policy-makers. This is why the European Council has stipulated that two thirds of R&D expenditure should be financed by the business sector.

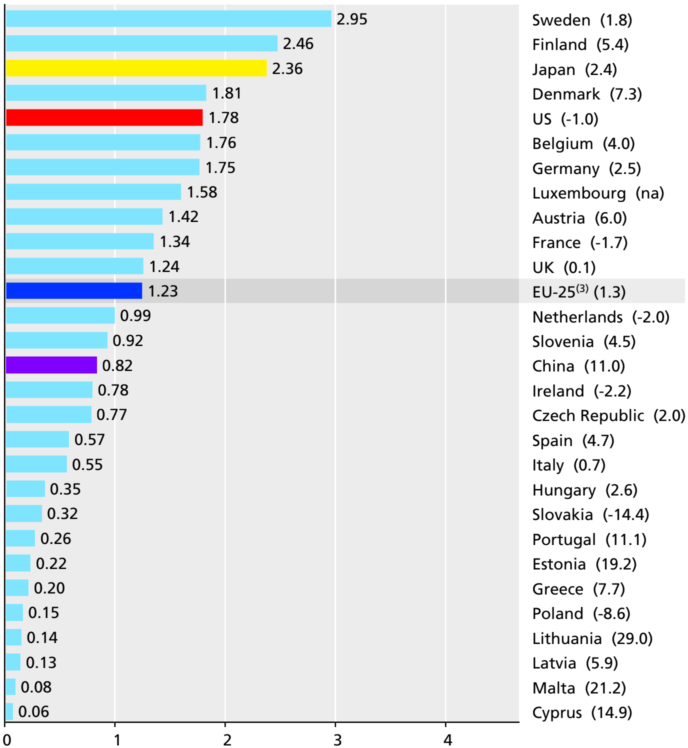
Business R&D intensity remains low in spite of healthy growth in several Member States

Business R&D intensity was only 1.23 % in 2003 in the EU compared to 1.78 % in the US and 2.36 % in Japan. The EU and Japan experienced an increase in business R&D intensity over 1997-2003 while the US experienced a decline. In China, R&D expenditure by the business enterprise sector is still below the EU-average at 0.82 % (of GDP), but it is already higher than in most new Member States, the southern European countries and Ireland. Furthermore, China's business R&D intensity has been growing rapidly at around

10 % per year over recent years. Among the EU countries, Sweden and Finland had the highest business R&D intensities, with values far above 2 %, while the majority of the new Member States as well as the southern European countries were below the EU average. Most of these countries nevertheless experienced sharp increases in business R&D intensity between 1997 and 2003. Among the countries with the highest R&D expenditure, Germany, France and the UK have business R&D intensities exceeding the EU average. France, however, saw a decline in its business R&D intensity during the period 1997-2003.

Business R&D is mainly funded by the business enterprise sector itself, but the contribution of that sector is much higher in the US and Japan than in Europe. In 2002, it amounted to 82.0 % in the EU compared to 98.1 % in Japan and 90.0 % in the US (the values for the US and Japan refer to 2003). The share of the business sector in the financing of business R&D varies widely across EU countries. It ranged from 35 % in Latvia to 96 % in Finland. Moreover, several low R&D intensive EU countries such as Portugal, Lithuania and Greece enjoy relatively strong business support for business R&D. Conversely, France combines a relatively high business R&D intensity with a share of the business sector in the funding of business R&D which is lower than the EU average.

Figure II.3.1 Business enterprise expenditure on R&D (BERD) as % of GDP, 2003(1); in brackets: average annual growth rates (%), 1997-2003(2)



Source: DG Research Key Figures 2005

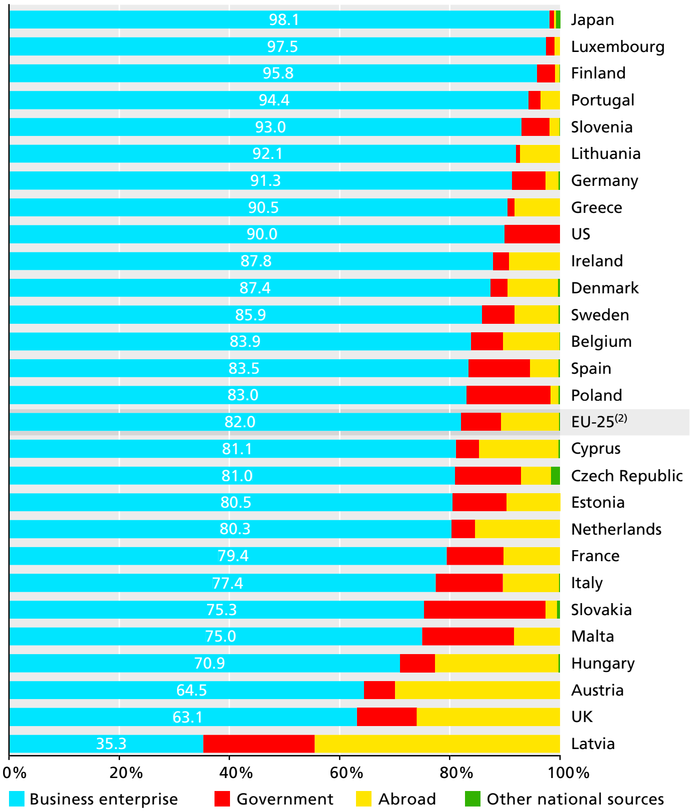
Data: Eurostat, OECD

Notes: (1) LU : 2000; AT : 2002; BE, IE, IT : 2004.

(2) ES : 1997-2001; BE, IE, IT : 1997-2004; EE, AT : 1998-2002; CY : 1998-2003; CN : 2000-2003; FR, UK : 2001-2003; MT : 2002-2003.

(3) EU-25 was estimated by DG Research and does not include LU and MT.

Figure II.3.2 BERD by main sources of funds, 2002(1)

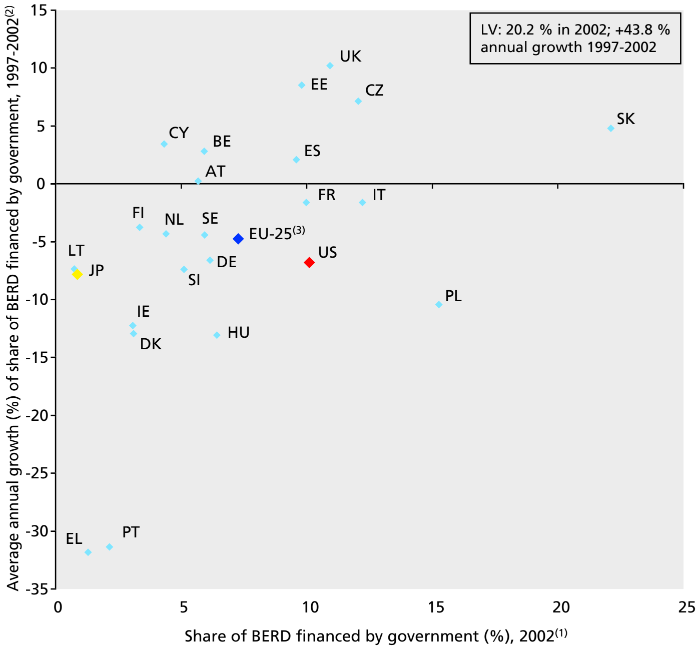


Source: DG Research Key Figures 2005
Data: Eurostat, OECD
Notes: (1) LU : 2000; DK, EL, PT : 2001; CZ, DE, ES, IE, HU, PL, SK, FI, SE, UK, US, JP : 2003.
(2) EU-25 was estimated by DG Research and does not include LU.

The financing of business R&D is changing

The roles of government and business sector in the financing of business R&D are changing. Between 1997 and 2002, the share of direct government funding declined significantly in the EU, Japan and the US (by -4 % to -7 % per year), although it remains non-negligible in the US and in the EU countries, especially in the new Member States and in France. Within Europe, the drop was particularly significant in Portugal and Greece. On the other hand, there were slight increases in the proportions of business R&D financed by the business sector in the EU and in the US (0.04 % and 1 % average annual growth respectively) between 1997 and 2002 (2003 in the case of the US). Within the EU, the share of business R&D funded by the business sector increased significantly in a few new Member States such as Latvia and Poland, as well as in Greece and in Portugal.

Figure II.3.3 Share of business enterprise expenditure on R&D (BERD) financed by government - latest year and average annual growth



Source: DG Research		Key Figures 2005

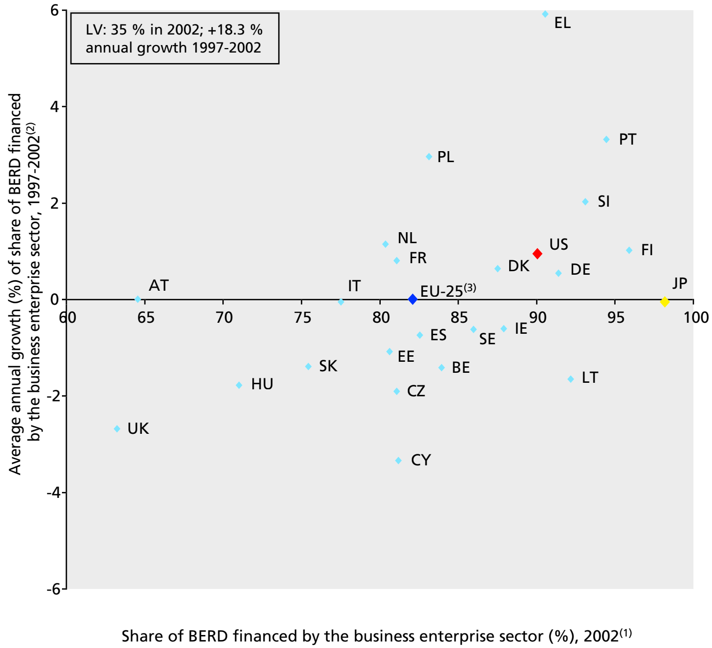
Data: OECD, Eurostat

Notes: (1) FR : 2000; DK, EL, ES, PT : 2001; CZ, DE, IE, HU, PL, SK, FI, SE, UK, US, JP : 2003.

(2) FR : 1997-2000; DK, EL, ES, PT : 1997-2001; CZ, IE, HU, PL, SK, FI, SE, US, JP : 1997-2003; EE, CY, AT : 1998-2002; DE : 1998-2003; LT : 2000-2002; UK : 2001-2003.

(3) EU-25 was estimated by DG Research and does not include LU and MT.

Figure II.3.4 Share of business enterprise expenditure on R&D (BERD) financed by the business enterprise sector - latest year and average annual growth



Source: DG Research		Key Figures 2005

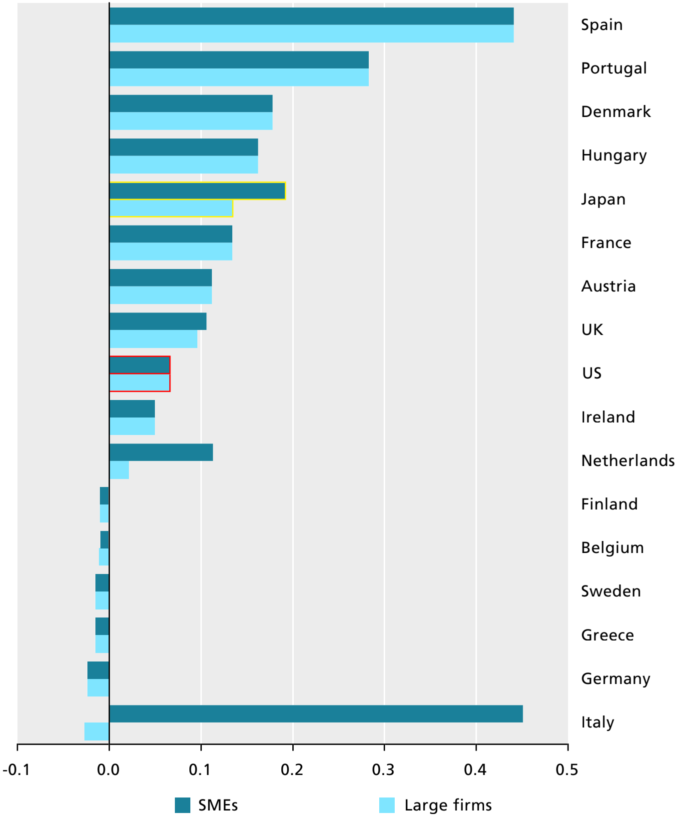
Data: Eurostat, OECD

Notes: (1) FR : 2000; DK, EL, ES, PT : 2001; CZ, DE, IE, HU, PL, SK, FI, SE, UK, US, JP : 2003.

(2) FR : 1997-2000; DK, EL, ES, PT : 1997-2001; CZ, IE, HU, PL, SK, SE, US, JP : 1997-2003; EE, CY, AT : 1998-2002; DE, FI : 1998-2003; LT : 2000-2002; UK : 2001-2003.

(3) EU-25 was estimated by DG Research and does not include LU and MT.

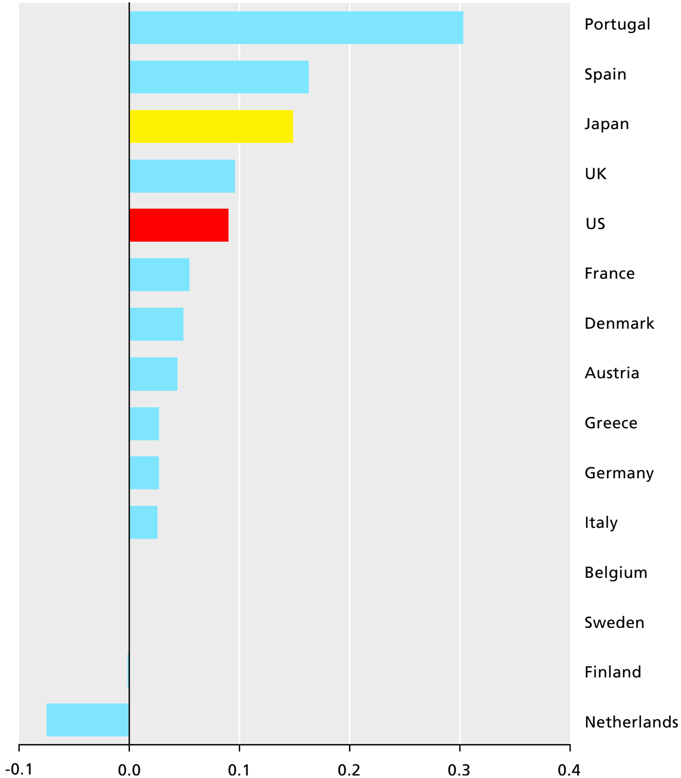
Figure II.3.5 Rate of tax subsidies for 1 EUR of R&D, large firms and SMEs, 2004



Source: DG Research
Data: OECD

Key Figures 2005

Figure II.3.6 Change in the rate of tax subsidies for 1 EUR of R&D, large firms, between 1995 and 2004



Source: DG Research
Data: OECD

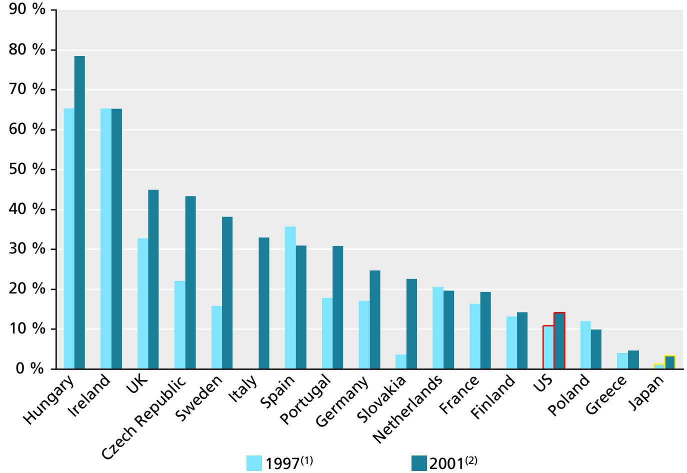
Key Figures 2005

While the share of direct government funding is decreasing, governments in many Member States are increasingly using indirect policy measures to encourage higher business R&D expenditure. In particular there are an increasing and diverse number of R&D tax incentives in many EU countries since the mid-1990s. Some of these new incentives are based on the level of R&D spending during a given year, others are targeted at SMEs (e.g. in Italy) or at identified R&D fields. Austria, France and the Netherlands have made more generous tax concessions. Germany has reduced its corporate tax rates to leave companies more resources for R&D. As a result, most of the EU countries saw an increase in the rate of tax subsidies since the mid-1990s. Tax incentives for R&D directed at large firms and at SMEs were particularly high in Spain, Portugal and Denmark in 2004. While many EU countries had approximately the same level of subsidies for both large firms and for SMEs, Italy and the Netherlands provided particularly generous incentives to small firms.

Europe is losing its attractiveness for international R&D investment

Recent years have seen increased globalisation of R&D. R&D expenditure by affiliates of foreign companies is increasingly contributing to R&D spending in most EU Member States, as well as in the US and Japan. The share of foreign affiliates in total R&D expenditure by enterprises has risen most noticeably in the new Member States Slovakia, the Czech Republic and Hungary, and in the UK, Sweden and Portugal. In Germany, France, Finland, the US and Japan, the increase was less marked but still substantial. In other countries, the shares remained relatively constant, which indicates that R&D by affiliates of foreign companies has increased in line with domestic R&D.

Figure II.3.7 R&D expenditure by foreign affiliates, 1997 and 2001(1) as % of R&D expenditure by business enterprise



Source: DG Research Key Figures 2005

Data: OECD (Activity of Foreign Affiliates database)

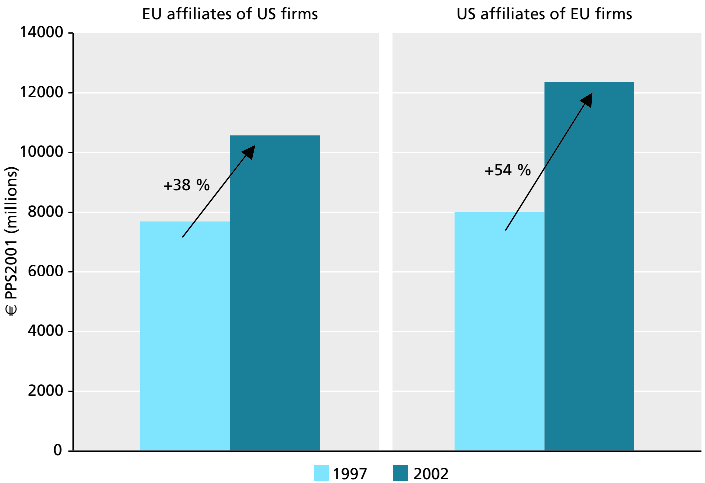
Notes: (1) SK : 1996; FR : 1998; PT : 1999; PL : 2000.

(2) HU : 1998; EL : 1999; CZ, FR, PL, SK, US : 2002; UK : 2003.

Since the mid-1990s, the US has experienced a gain in its share of foreign affiliates R&D spending. A large part of this shift towards the US came from EU companies having affiliates on US territory. Between 1997 and 2002, R&D expenditures of US-based affiliates of EU manufacturing firms increased by 54 % in real terms, from approximately 8 billion to more than 12 billion (€2001 PPS). US firms increased their R&D expenditure in EU-based affiliates by 38 %, from 7.6 billion to 10 billion (€2001 PPS). As a result, the net gain for the US increased by a factor of 5.4 over recent years, from about 300 million in 1997 to almost 2 billion in 2002 (€2001 PPS).

During that period, foreign R&D investments in the US were mainly targeted at high-technology areas. Pharmaceuticals and communication equipment alone accounted for more than half of the R&D expenditures by foreign affiliates in 2000[11]. These data tend to confirm that companies increasingly locate new R&D facilities near centres of scientific and technological excellence, not just near markets of interest.

Figure II.3.8 Expenditure on manufacturing R&D by foreign affiliates, 1997 and 2002



Source: DG Research

Key Figures 2005

Data: OECD (Activity of Foreign Affiliates database)

Notes: (1) SK : 1996; FR : 1998; PT : 1999; PL : 2000.
(2) HU : 1998; EL : 1999; CZ, FR, PL, SK, US : 2002; UK : 2003.

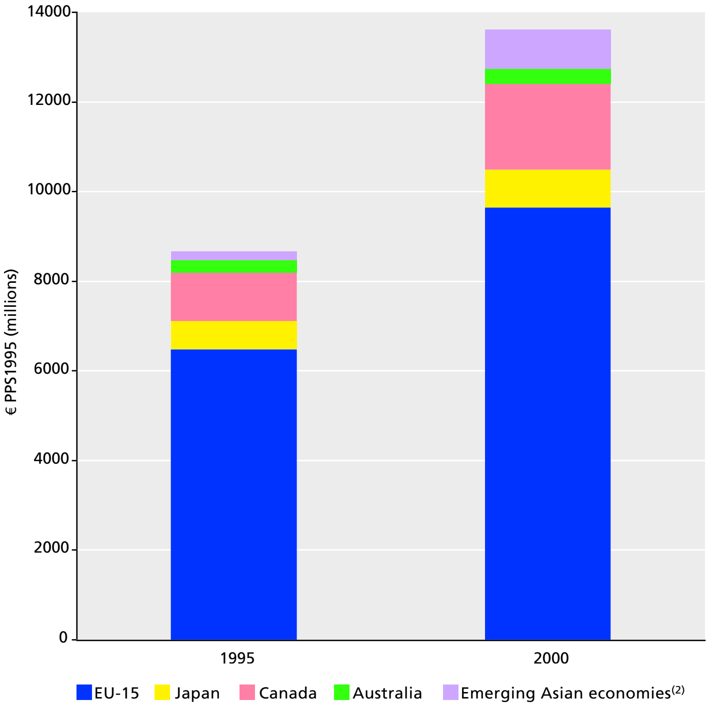
11. OECD (2004), Science, Technology and Industry Outlook, OECD: Paris.

Although there is evidence to show that EU companies might benefit from this 'technology-sourcing' thanks to knowledge spill-overs to the parent company resulting in increased marginal productivity at company level in the region of origin, such a net outflow also reflects the relatively stronger attractiveness of the US research and innovation systems compared to those of the EU. It risks leading Europe into a worrying vicious circle as the loss of high value-added R&D activities and jobs undermines further its capacity to retain such activities.

Furthermore, US outward R&D investment grew over recent years in all major regions of the globe, but growth has been fastest outside EU-15, particularly in emerging countries such as China, where US outward R&D investment increased by 25 % per year since the mid-1990s (against 8 % per year in EU-15). As a result, the EU-15 share in total US outward R&D investment has been declining since the late 1990s. These trends are expected to continue as long as new actors build up their science and technology infrastructures and open their markets to foreign entrants.

Therefore, policy measures to increase the attractiveness of the European Knowledge Area are an important means of increasing business R&D intensity and generating spill-overs that can be beneficial to EU firms. Specific attention needs to be paid to the development of policies that may attract or retain high R&D-intensive companies.

Figure II.3.9 US overseas R&D expenditure, 1995 and 2000(1)



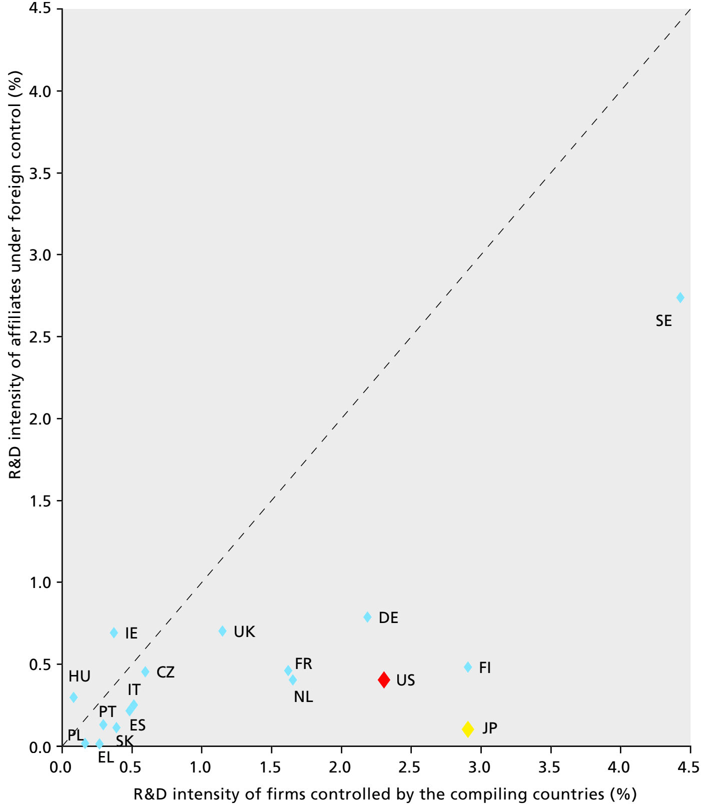
Source: DG Research Key Figures 2005

Data: US Bureau of Economic Analysis : US Direct Investment Abroad - Operations of US parent companies and their foreign affiliates (Washington DC, annual series).

Notes: (1) US overseas R&D expenditure refers to R&D expenditure performed by majority-owned (more than 50 % ownership) non-bank foreign affiliates of non-bank US parent companies. Data include R&D expenditures conducted by affiliates, whether for themselves or for others under contract; exclude R&D expenditures conducted by others for affiliates under contract.

(2) Emerging Asian economies: China, Hong Kong, Singapore and Taiwan.

Figure II.3.10 R&D intensity of foreign companies and national firms as % of value added in industry, 2001(1)



Source: DG Research Key Figures 2005

Data: OECD.

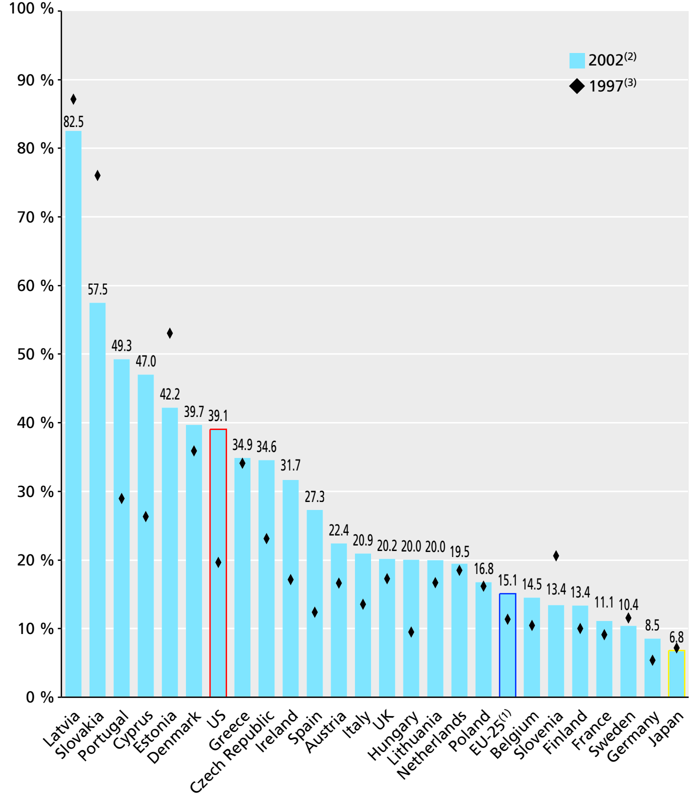
Notes: (1) HU : 1998; EL : 1999; TR : 2000; CZ, SI, UK : 2002.

EU-based firms tend to invest less than US firms in R&D in the services sector and in high-tech manufacturing

In the US, nearly 40 % of all business R&D is performed in the services sector, whereas in the EU this share is only 15 %. However, since 1997, an increasing proportion of business R&D is being performed in the services sector in Europe (from 11.5 % in 1997 to 15.1 % in 2002). The increasing importance of services sector R&D is mainly due to three factors: an improvement in the measurement of services sector R&D; a growth in R&D intensity in the services sectors and an increase in the outsourcing of R&D by both the business and government sectors. Within Europe, the shares of R&D expenditure performed in the services sector vary greatly. The share of R&D performed in the services sector remains particularly low in a few key EU countries, namely Germany, Sweden, France and Finland.

In 2002, the share of high-tech manufacturing industries in total manufacturing R&D expenditure was at almost the same level in the EU (41 %) and Japan (42 %) whereas the share for the US was higher at 44 %. European industrial R&D is more likely to be concentrated in medium-high-tech manufacturing. There are sharp national differences within Europe in the distribution of manufacturing R&D by technology intensity. The share of manufacturing R&D performed in high-tech industries amounted to more than 60 % in Finland, Hungary and Ireland compared to just 26.6 % in Germany, which, however, has a very high concentration of R&D in medium-high-tech manufacturing.

Figure II.3.11 Share of BERD performed in the services sector (%)



Source: DG Research Key Figures 2005
Data: Eurostat, OECD
Notes: (1) EU-25 was estimated by DG Research and does not include LU and MT.
(2) AT : 1998; EL, IE, PT : 2001; CZ, DE, IT, HU, PL, SK, FI, SE, : 2003.
(3) AT : 1993; EE, CY : 1998; LV : 2000; JP : 2001.

Table II.3.1 Manufacturing BERD by type of industry, 2002[1]

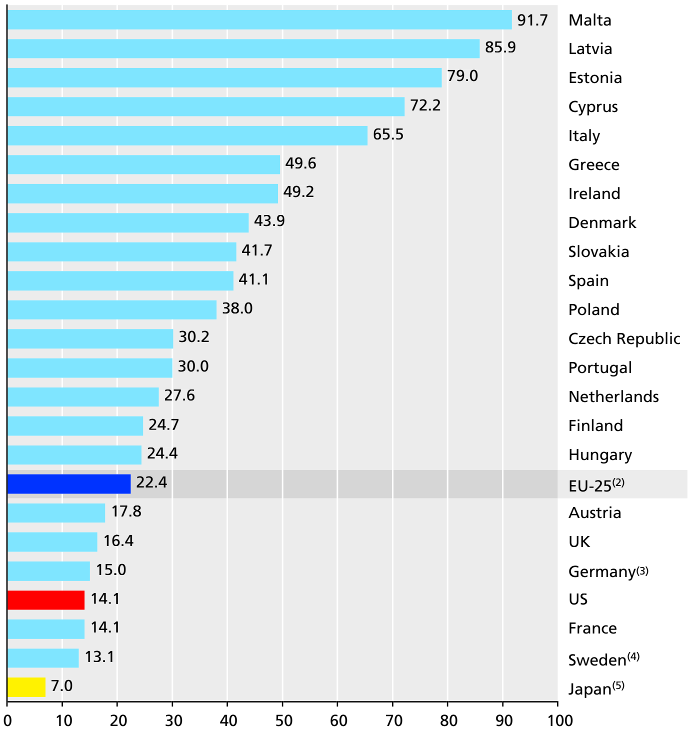
	High-Tech	Medium-High-Tech	Medium-Low-Tech and Low-Tech
Czech Republic	14.9	70.5	14.6
Germany	26.6	65.6	7.7
Malta	28.5	42.8	28.6
Latvia	29.3	45.5	25.2
Poland	34.2	45.9	20.0
Spain	36.0	41.8	22.3
Italy	40.9	47.5	11.5
EU-25[2]	41.4	47.7	10.9
Japan	41.6	45.9	12.5
Cyprus	43.8	27.3	28.9
US	44.3	44.9	10.8
France	44.6	42.0	13.4
Denmark	46.1	39.3	14.6
Netherlands	46.4	36.4	17.2
Belgium	49.8	31.6	18.6
Slovenia	51.7	32.8	15.5
Sweden	52.2	40.4	7.4
UK	56.7	33.6	9.6
Finland	62.6	23.4	14.0
Ireland	64.3	19.0	16.7
Hungary	64.9	26.0	9.1

Source: DG Research Key Figures 2005
Data: OECD, Eurostat
Notes: (1) IE : 2001; CZ, DE, IT, FI, SE : 2003.
(2) EU-25 does not include : EE, EL, IE, LT, LU, AT, PT, SK.

SMEs perform a relatively large part of business R&D in the EU

Small and medium-sized firms account for a higher share of business R&D in the EU than in the US and Japan, performing 22 % of business R&D in 2002. Countries that are characterised by a relatively high participation of SMEs in business R&D, such as the new Member States, Italy, Greece and Spain, also have low business R&D intensities. Conversely, countries with low concentrations of business R&D in SMEs – e.g. Sweden, France, Germany, Austria, Japan and the US – also have higher business R&D intensities. Countries with low R&D intensities and relatively less developed research systems often lack the minimum scale to host large R&D intensive companies, which in turn explains the predominance of SMEs in their total business R&D expenditure. This observable correlation between low R&D intensity and high participation of SMEs, however, does not apply to Denmark, where the high R&D intensity (the third highest in the EU) is largely driven by small and medium-sized enterprises.

Figure II.3.12 Share of BERD performed by SMEs (%), 2002(1)



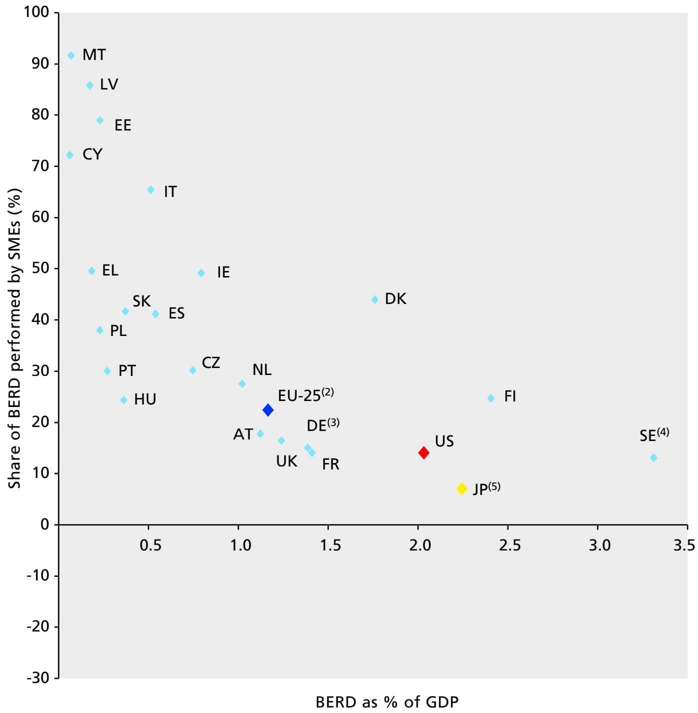
Source: DG Research
Key Figures 2005
Data: Eurostat, OECD (STI/EAS)
Notes: (1) AT : 1998; DE, EL : 1999; US : 2000; IE, IT, PL, PT, SE, UK, JP : 2001.
(2) EU-25 does not include : BE, DE, EL, IE, IT, LT, LU, AT, PL, PT, SI, SE, UK.
(3) DE : Institutes are not included.
(4) SE : Size class - 50-249 employees.
(5) JP : Size class - less than 300 employees.

The higher concentration of R&D expenditure in small and medium-sized companies should not be a problem if this supports company expansion. Empirical evidence, however, shows that, if some SMEs (particularly the high-tech ones, often labelled 'New Technology-based firms' or NTBFs) can grow rapidly and become critical players in many industry sectors (e.g. Microsoft, Cisco, Sun Microsystems, Hewlett-Packard), the typical growth path of such an SME is more likely to be successful in the US than in Europe. According to data on the growth paths of large companies in both the EU and the US, only 16 % of the EU's current largest companies have been established after 1980 as against 30 % in the US. Out of these large companies created after 1980, only 37 % were created from scratch (the remainder being the result of mergers and acquisitions) in the EU compared to 82 % in the US[12].

It is therefore essential to support the creation and expansion of SMEs, especially in high and medium-high technology intensive sectors and to ensure that the right conditions exist for SMEs to flourish and for Europe, as a consequence, to achieve its R&D potential.

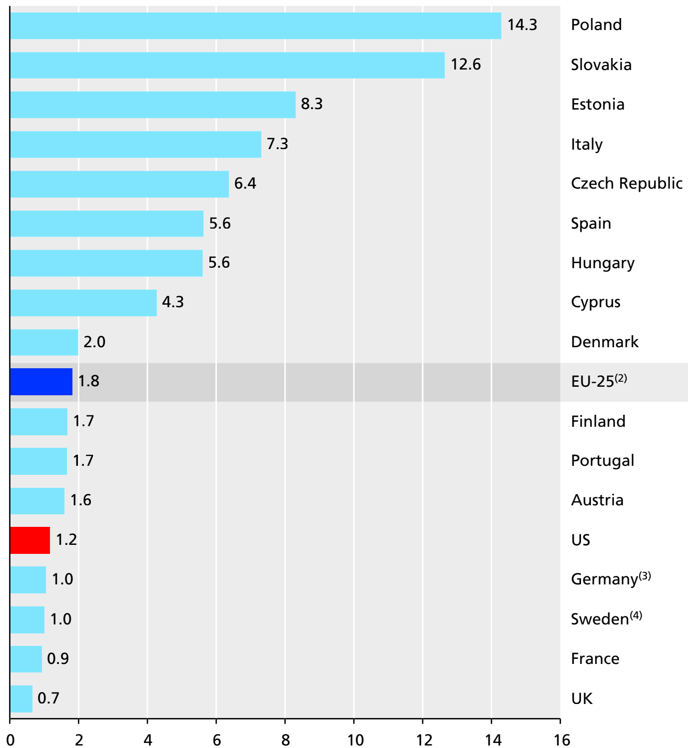
12. Cohen, E. and Lorenzi, J.-H. (2000), Politiques industrielles pour l'Europe, Paris, Conseil d'Analyse Économique.

Figure II.3.13 BERD as % of GDP and % share of BERD performed by SMEs, 2002(1)



Source: DG Research
Key Figures 2005
Data: Eurostat, OECD (STI/EAS)
Notes: (1) AT : 1998; DE, EL : 1999; US : 2000; IE, IT, PL, PT, SE, UK, JP : 2001.
(2) EU-25 does not include : BE, DE, EL, IE, IT, LT, LU, AT, PL, PT, SI, SE, UK.
(3) DE : Institutes are not included.
(4) SE : Size class - 50-249 employees.
(5) JP : Size class - less than 300 employees.

Figure II.3.14 Publicly funded R&D executed by SMEs in the business sector as % of total BERD, 2002(1)



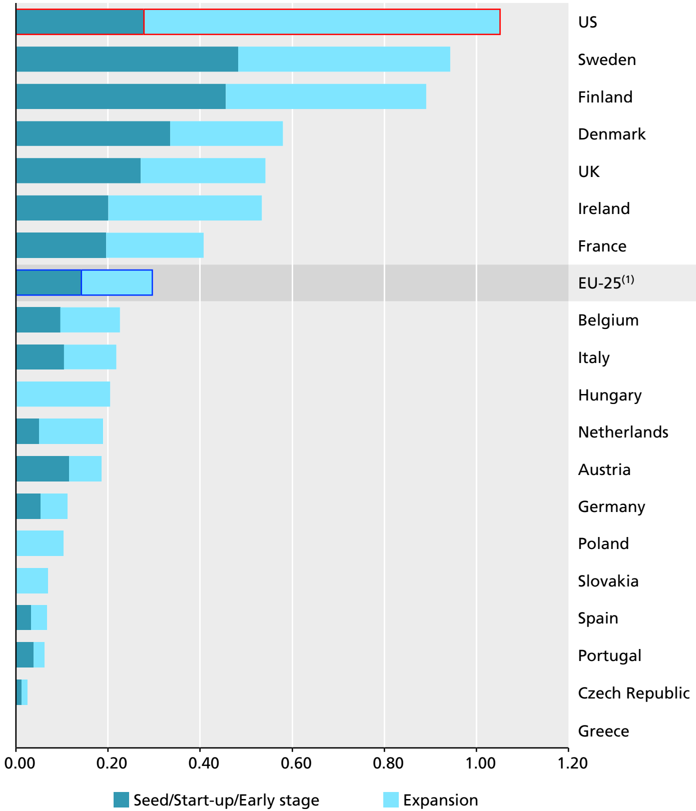
Source: DG Research
Key Figures 2005
Data: Eurostat, OECD (STI/EAS).
Notes: (1) AT : 1998; DK, DE : 1999; US : 2000; IT, PL, PT, SE, UK : 2001.
(2) EU-25 does not include : BE, DK, DE, EL, IE, IT, LT, LV, LU, MT, NL, AT, PL, PT, SI, SE, UK.
(3) DE : Institutes are not included.
(4) SE : Size class – 50 - 249 employees

Less opportunities for technology venture capital

Large firms tend to finance most of their R&D effort from profits. In their case, public policy tends to stimulate activities at the margin only. For smaller firms, however, access to venture capital is often a decisive factor in R&D investment decisions. In other words, venture capital can play a critical role in the creation and expansion of R&D-intensive SMEs because the anticipated research effort is likely to be beyond their financial capacity. Venture capital (VC) investment can finance the seed, start-up and expansion phases of a firm's life cycle. It provides equity capital and managerial skills for high risk, promising new companies, which frequently are found in high-tech and knowledge-intensive sectors. Therefore, venture capital investment creates and expands new business activities that generate additional business sector R&D and drive competitiveness and economic growth.

In terms of venture capital investment relative to GDP in the high tech sectors, the EU is lagging behind the US. In 2003, the US's total investment in venture capital in these sectors was 1.05 per thousand GDP, which is about three times the amount invested in the EU. The EU countries with strongest high-tech venture capital investment rates also tend to be those with the highest R&D intensities. Sweden and Finland, for instance, show levels of high-tech venture capital investment comparable to the US. US early stage venture capital investment in the high-tech sectors was twice as high as that of EU-25 in 2003. Moreover, three quarters of the high-tech venture capital investment within the US is made at the expansion stage, whereas only about half is invested at the expansion stage in Europe.

Figure II.3.15 High-tech venture capital by stage per 1000 GDP, 2003



Source: DG Research Key Figures 2005
Data: PriceWaterhouseCoopers (Moneytree Survey, Money for Growth 2004)
Notes: (1) EU-25 does not include EE, LU, CY, LV, LT, LV, MT and SI.

A recent study by the European Commission, based on comparable data, further analyses early-stage technology venture capital investment and points to three major differences between the EU and the US[13]. Firstly, the number of high-tech companies benefiting from early stage venture capital investment is much larger in Europe (twice as much as in the US in 2003). It can realistically be assumed that Europe does not generate twice as many technological innovations as the US, but that on average a larger proportion of new projects was financed by venture capital than in the US. Secondly, the average investment in a technology company is much larger in the US (in 2003, the average deal size in a high-tech company was about nine times higher than in the EU). A difference of this magnitude cannot be explained by cost level differentials (i.e. the cost of getting a new technology business under way) on both sides of the Atlantic or by differences in the destination of venture capital Investment (the sectoral breakdown being largely the same in the EU and in the US). Thirdly, there is a significant disparity between the US and the EU in the profitability of early stage venture capital investment: in 2003, average internal rates of return were about 30 to 50 times higher in the US. Since there is no reason to assume that European technological innovations would be of inferior quality, explanations for this poor investment performance should be sought elsewhere.

Examined against the backdrop of the low profitability rate and the dispersion of EU early stage investment, we can conclude that a large part of the small investments made by EU funds fail as a result of the technology having been too immature for venture financing. US venture capitalists appear to be more successful at concentrating their investment on more advanced projects/technologies that are generating better profits. From the point of view of the innovating companies, European research teams incorporate and seek venture capital at a too early stage, when clearly, on average, the uncertainties are still too high for both parties. Therefore, the main problem for Europe consists less of an underperforming venture capital industry (supply side) than of the level of development of projects prior to early stage financing (demand side). In other words, the financing of commercialisation of technological innovation cannot be solved solely through actions aimed at strengthening venture capital funds specialised in early stage investment. It needs to be assessed in a more systemic way, improving the links between universities and industry and the quality of mechanisms for technology transfer.

13. European Commission (2005), "The shifting structure of private equity funding in Europe. What role for early stage investment?", (ECFIN/L/6(2005)REP/51515-EN).

II-4. Public sector R&D and its relationship with the business enterprise sector

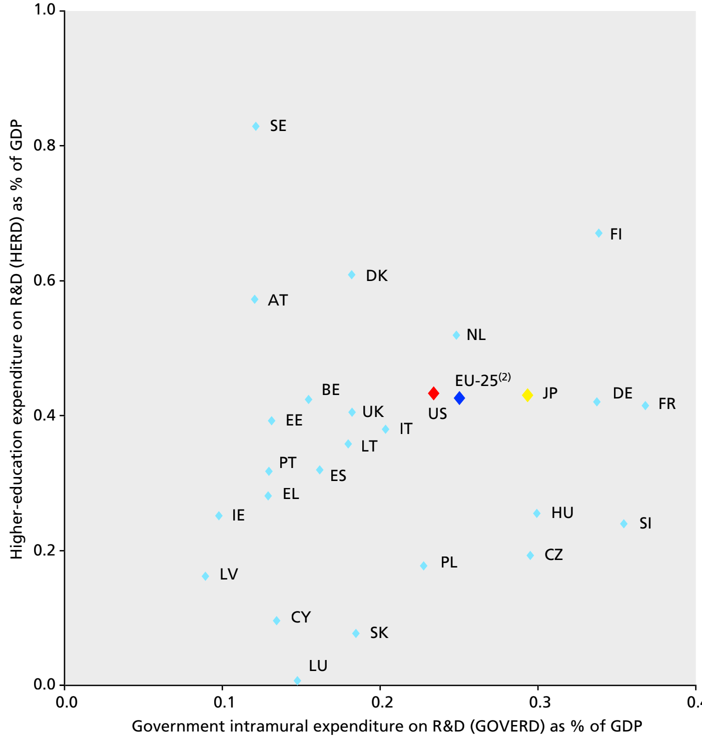
Public sector R&D can boost business R&D spending in several ways. It creates and expands the stock of knowledge that firms can build upon. The higher education sector trains highly-skilled graduates for industry; it develops new instruments and provides research infrastructures that can be fruitful for industrial R&D activity. Furthermore, a strong public research sector can attract investments from foreign-owned companies, especially via the concentration of resources in centres of excellence. Finally, through the formation of public-private research networks and the creation of new firms, the public research sector helps enhance the capacity for R&D problem solving.

R&D expenditure in the higher education sector is on the rise in the EU ...

R&D performed in the higher education sector is on the rise in Europe, Japan and the US. In 2003, higher education expenditure on R&D as % of GDP amounted to 0.44 % in the EU as a whole, well above its 1997 level (0.38 %). Within the EU, the three Nordic countries Sweden, Finland and Denmark showed the highest intensity of higher education R&D in 2003, with values above 0.60 %. Austria and the Netherlands were also above the EU average. On the other hand, most of the new Member States (except Lithuania and Estonia) were far below the EU average. In both the US and Japan, higher education expenditure on R&D in relation to GDP amounted to 0.43 % in 2003, compared to 0.37 % and 0.41 % respectively in 1997.

In the EU, as well as in Japan and in the US, the intensity of R&D performed in the higher education sector is much higher than that of R&D performed in government institutions. In 2003 the latter reached 0.25 % in the EU and 0.23 % in the US, compared to 0.30 % for Japan in 2002. In recent years, the intensity of government R&D has followed a downward trend in the EU while it has increased in the US and Japan between 1997 and 2003.

Figure II.4.1 Public R&D in relation to GDP, 2003(1)



Source: DG Research Key Figures 2005

Data: Eurostat, OECD

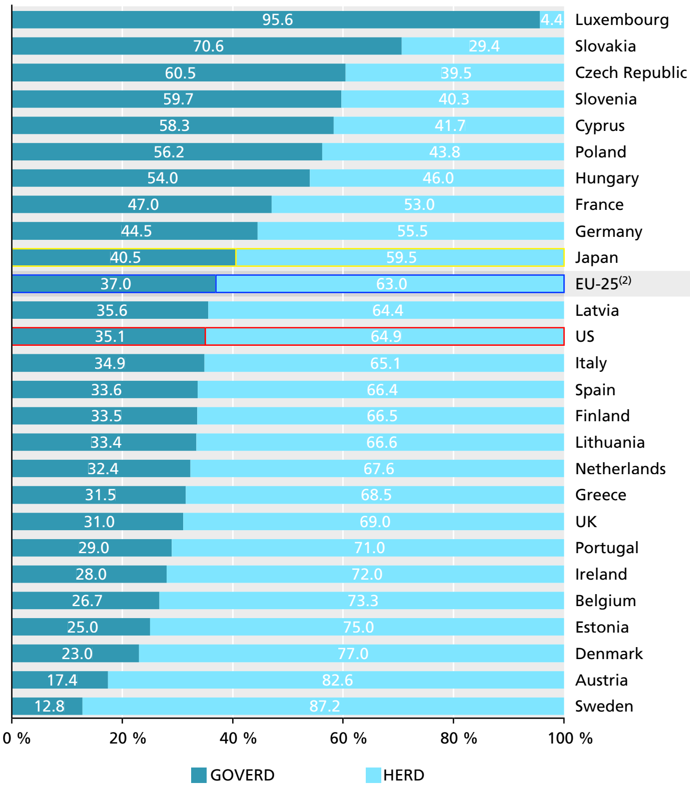
Notes: (1) LU, SE : 2001; AT, IE, IT, NL : 2002; BE : 2004.

(2) EU-25 was estimated by DG Research and does not include LU and MT.

... But government R&D remains quite substantial in the new Member States

In the EU, there is a marked difference between the old and the new Member States where the organisation of public R&D is concerned. Whereas in the established EU Member States most public expenditure on R&D is executed by the higher education sector, in the new Member States (with the exceptions of Lithuania, Latvia and Estonia) a sizeable share of public R&D is performed in the government sector. An expansion of higher education R&D is required in these countries in order to facilitate more academic research and also to enable the training of more highly-skilled scientists and engineers for the business sector.

Figure II.4.2 Shares of government and higher education R&D expenditure in total public expenditure on R&D (%), 2003[(1)]



Source: DG Research Key Figures 2005

Data: Eurostat, OECD

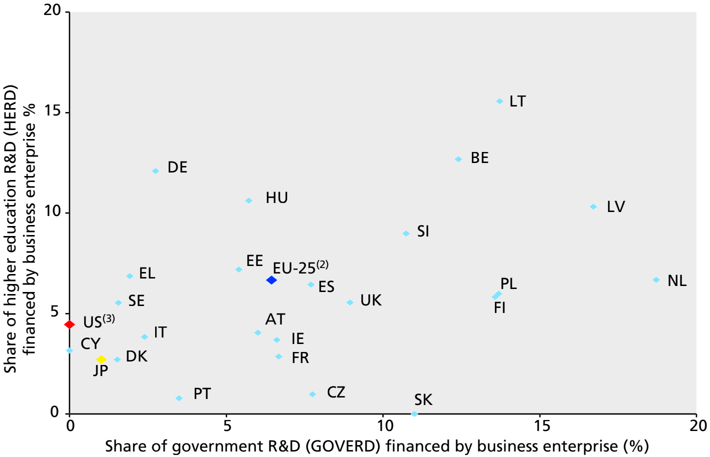
Notes: (1) LU, SE : 2001; IE, IT, NL, AT : 2002; BE : 2004.

(2) EU-25 was estimated by DG Research and does not include LU and MT.

Firms are financing public R&D substantially

Business support for R&D in the higher education sector is substantially higher in the EU (6.6 %) than in either the US (4.5 %) or Japan (2.6 %). In 2002, the differences between Europe and its competitors in the levels of government R&D funded by the business sector were even wider. In terms of growth, only Japan showed positive growth rates in the levels of private funding of both public sectors. In Europe growth can only be witnessed in the level of higher education R&D financed by the business sector.

Figure II.4.3 Shares of government R&D and higher education R&D financed by business enterprise (%), 2002(1)



Source: DG Research Key Figures 2005
Data: Eurostat, OECD
Notes: (1) IT : 1996; BE, EL, PT, SE : 2001; CZ, DK, DE, ES, HU, PL, SK, FI, UK, US, JP : 2003.
(2) EU-25 was estimated by DG Research and does not include LU and MT.
(3) US : GOVERD refers to federal or central government only.

In Europe, the largest shares of government R&D financed by the business sector are found in the Netherlands and Latvia, in each case exceeding 15 %. More than 10 % of R&D performed in the higher education sector is funded by the business sector in Lithuania, Belgium, Germany, Hungary and Latvia. Hungary also experienced the highest growth between 1997 and 2002 – more than 30 %. Among the most important R&D performing countries, France and the UK show a stronger business support for government R&D whereas Germany's business enterprise sector prefers to fund higher education R&D.

II-5. Human resources in science and technology

Neither R&D – nor other S&T activities – are possible without human resources. If the R&D expenditure target of 3 % of GDP is to be achieved, ensuring that there are sufficient human resources for research is a preliminary step in the right direction. To this end, the European Commission advocates increasing the proportions of researchers in the labour force from five to eight per thousand[14]. This section first analyses the current level and growth of the EU's S&T labour force by examining recent developments in the numbers of researchers, and the size and age structure of the S&T workforce. It then looks at factors influencing the expansion of the stock of human resources, examining both the supply (investment in education, numbers of graduates, the participation of women) and demand (attractiveness of research careers) sides of the equation.

14. European Commission (2004), Science and Technology - The Key to Europe's Future; COM(2004)353.

Box 5. Researchers and human resources in science and technology

According to the OECD Frascati Manual, researchers are professionals engaged in the conception or creation of new knowledge, products, processes, methods and systems and also in the management of the projects concerned. Researchers are classified in ISCO-88 Major Group 2 (sub-major groups 21, 22, 23, 24), "Professionals", and in "Research and Development Department Managers" (ISCO-88, 1237).

Human resources in science and technology (HRST) comprise people who have successfully completed education at the third level in a S&T field of study (natural sciences, engineering and technology, medical sciences, agricultural sciences, social sciences and humanities –Canberra Manual, ∫71) and also people who although not formally qualified in this way are employed in a S&T occupation where such qualification is normally required (corresponding to professionals and technicians – ISCO-88 (International Standard Classification of Occupations) levels 2 and 3 and also certain managers, ISCO 121, 122 and 131). Human resources in science and technology – Core (HRSTC) comprise people who have successfully completed education at the third level in a S&T field of study and are employed in a S&T occupation.

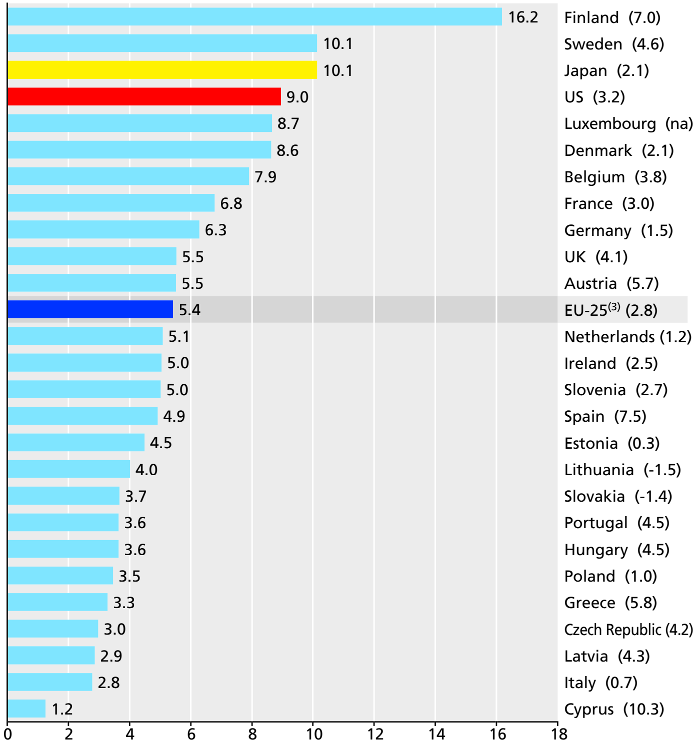
II-5.1. The S&T labour force in the EU

The pool of researchers is much smaller than in the US and Japan ...

In 2003, the number of full-time equivalent (FTE) researchers per one thousand labour force was only 5.4 in the EU, compared to 10.1 in Japan and 9 in the US. Despite this gap between the EU and its main competitors, the number of researchers per one thousand labour force has been growing at an average annual rate of 2.8 % in the EU over recent years, much higher than the growth in R&D intensity.

Not surprisingly, Finland and Sweden – the countries with the highest R&D intensities – also have the highest numbers of researchers per one thousand labour force (more than ten) in Europe. The low R&D intensive countries such as the new Member States and the southern European countries have smaller proportions of researchers. Many EU countries enjoyed a significant increase in the number of researchers in the labour force between 1997 and 2003, even though their R&D intensities increased only slowly or even declined in some cases. However, in Italy, Slovakia, Estonia and Lithuania, growth in the number of researchers per one thousand labour force has been either negative or relatively slow, especially when compared with the significant increases in their R&D intensities in recent years.

Figure II.5.1.1 Number of researchers (FTE) per 1000 labour force, 2003(1); in brackets: average annual growth rates (%), 1997-2003(2)



Source: DG Research
Key Figures 2005
Data: Eurostat, OECD
Notes: (1) UK : 1998; US : 1999; LU : 2000; EL, SE : 2001; FR, IE, IT, NL, AT : 2002; BE : 2004.
(2) UK : 1996-1998; US : 1997-1999; DK, EL, SE, JP : 1997-2001; FR, IT, NL : 1997-2002; BE : 1997-2004; AT : 1998-2002; EE, CY : 1998-2003; IE : 2000-2002.
(3) EU-25 was estimated by DG Research and does not include LU and MT.

... Particularly in the business sector

Europe not only has a smaller pool of researchers than the US or Japan, the business sector, which accounts for the bulk of R&D performance, also has a lower share of researchers. In the US, four out of five researchers are working in the business sector as are two out of three researchers in Japan. In the EU, just under half of all researchers are working in the business sector, just over a third are working in higher education and most of the rest are working in government research institutions.

Within Europe, the share of researchers employed in business enterprises varies between 6.7 % in Lithuania and 85 % in Luxembourg. Among the countries with high levels of expenditure on R&D, Germany has the highest share of business sector researchers (58.1 %), followed by the UK (57.9 %). Countries with low shares of business enterprise expenditure on R&D – namely the new Member States and the southern European countries – also have low proportions of business researchers. However, these countries have generally experienced higher than average increases in the proportions of business sector researchers since 1997.

Table II.5.1.1 Researchers (FTE) by institutional sector

	Total Researchers 2003(1)	in % by sector, 2003(1)			Average annual growth rates of sectoral shares (%), 1997-2003(2)		
		Business enterprise	Government	Higher education	Business enterprise	Government	Higher education
Belgium	36167	57.2	7.4	34.6	0.8	4.1	-1.8
Czech Republic	15809	41.5	30.6	27.3	0.3	-2.9	3.2
Denmark	25130	59.7	9.3	30.5	3.7	-3.4	-3.1
Germany	264721	58.1	14.7	27.2	0.5	-1.2	-0.4
Estonia	2976	15.6	16.1	66.3	9.8	-5.4	-0.7
Greece	14371	26.4	13.8	59.5	12.4	-6.6	-2.2
Spain	92523	29.8	16.7	53.2	1.5	-3.8	0.8
France	186420	51.1	12.9	34.1	1.6	-0.4	-1.9
Ireland	9386	63.8	6.4	29.8	4.7	-5.7	-4.6
Italy	71242	39.3	19.0	39.7	-1.3	-1.8	1.4
Cyprus	460	27.2	23.9	44.6	9.4	-7.0	0.2
Latvia	3203	14.5	16.1	69.4	8.3	-13.9	5.1
Lithuania	6606	6.7	25.5	67.8	26.4	-6.6	2.2
Luxembourg	1646	85.0	13.6	1.3	:	:	:
Hungary	15180	29.5	31.2	39.2	1.3	-1.9	0.7
Netherlands	43539	46.9	15.6	36.4	2.7	-1.5	-2.7
Austria	24124	66.3	4.1	28.9	1.5	-5.1	-2.4
Poland	58595	11.7	22.6	65.6	-8.5	1.2	1.8
Portugal	19766	19.4	16.2	51.4	14.2	-4.5	-1.1
Slovenia	4789	36.2	32.0	28.3	1.0	-1.4	-0.1
Slovakia	9626	19.9	25.3	54.8	-8.5	0.4	4.8
Finland	41724	56.6	11.3	31.2	1.4	-4.6	-0.6
Sweden	45995	60.6	4.9	34.5	1.7	-7.2	-1.5
UK	157662	57.9	9.1	31.1	1.0	0.6	-2.1
EU-25(3)	1178237	49.0	13.4	36.5	0.9	-2.5	-0.2
US	1261227	80.5	3.8	14.7	0.8	-6.1	-2.1
Japan	675330	67.9	5.0	25.5	-0.4	0.8	1.6

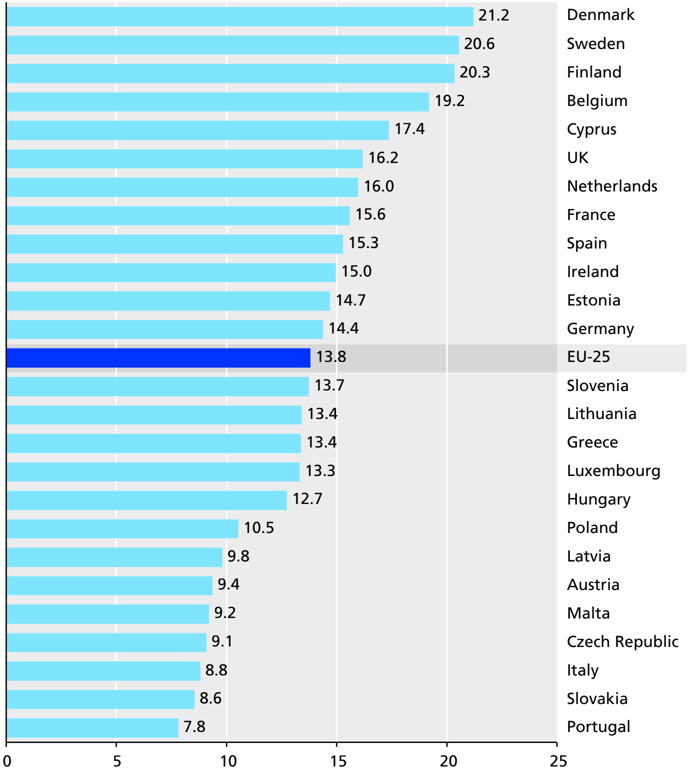
Source: DG Research Key Figures 2005
Data: Eurostat, OECD
Notes: (1) UK : 1998; US : 1999; LU : 2000; EL, SE : 2001; FR, IE, IT, NL, AT : 2002; BE : 2004.
(2) UK : 1996-1998; IE, NL, US : 1997-1999; DK, EL, ES, SE, JP : 1997-2001; FR, IT : 1997-2002; AT : 1998-2002; CY : 1998-2003, BE 1998-2004.
(3) EU-25 was estimated by DG Research and does not include LU and MT.

The ageing of the S&T labour force is becoming a concern in many Member States

The role of human resources educated and employed in S&T occupations (the 'highly qualified S&T workers') in knowledge-driven economies is fundamental because they contribute directly to the expansion of R&D activities and to the development of technological innovations.The importance of this S&T labour force varies across Europe from more than one fifth of the labour force in Denmark, Sweden and Finland to less than one twelfth in Portugal. As one might expect, high R&D intensive countries have the largest shares of core S&T workers in the total labour force.

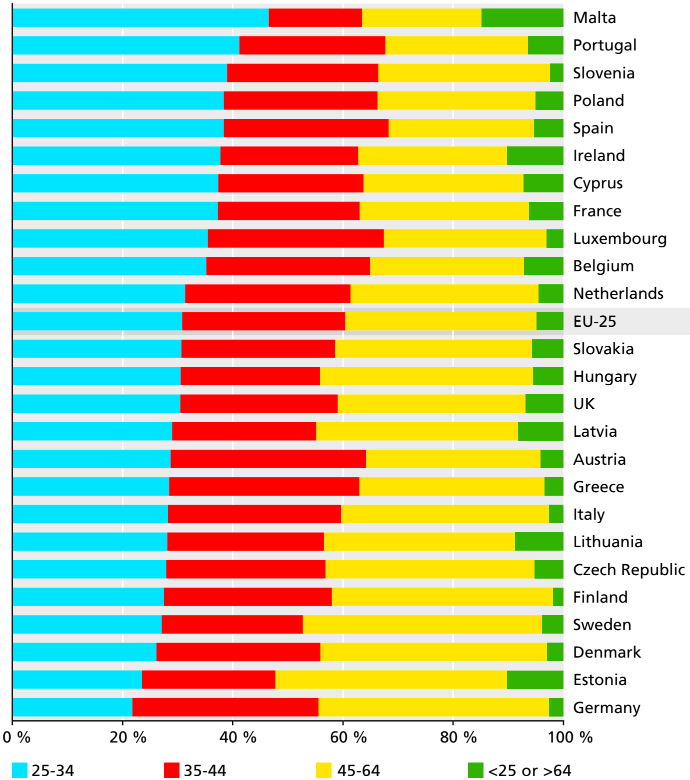
In several countries, concerns are rising about the ageing of the S&T labour force. In the EU-25 as a whole, about 35 % of highly qualified S&T workers were in the 45-64-year-old age group in 2003, compared to 31 % in the 25-34 age group. In Germany, Estonia, Denmark, Sweden and Finland the age distribution of the highly qualified S&T workforce is skewed towards the older age groups. In these countries, more than 40 % of the highly qualified S&T workforce is aged between 45 and 64, while the youngest group represents only about 25 % of the highly qualified S&T workforce (only slightly above 20 % in Germany).The situation is of particular concern in Estonia and Sweden because of the relatively low proportions of the 35-44 age group.These countries may face significant difficulties concerning the replacement of the retiring S&T labour force in the coming years. On the other hand, Belgium, Luxembourg, Portugal and Spain have the lower proportions of highly qualified S&T workers in the 45-64 age group and the largest shares in the 25-34 age group.

Figure II.5.1.2 Highly qualified scientific and technical workers[1] as % of total labour force, 2003[2]



Source: DG Research
Key Figures 2005
Data: Eurostat
Notes: (1) Highly-qualified scientific and technical workers refer here to the group of people educated AND employed in Science and Technology (HRSTC; see Box 5).
(2) NL : 2002.

Figure II.5.1.3 Highly qualified scientific and technical workers[1] - % distribution by age group, 2003[2]



Source: DG Research
Key Figures 2005
Data: Eurostat
Notes: (1) Highly qualified scientific and technical workers refer here to the group of people educated AND employed in science and technology (HRSTC).
(2) NL : 2002.

II-5.2. Expanding the stock of human resources for science and technology

The global financial commitment to tertiary education is low in the EU ...

Investment in education, especially in tertiary education, is seen as a crucial factor for Europe's transition towards the knowledge-based economy since it impacts on the supply of new graduates. The enlarged EU, however, devotes a much lower share of its wealth to the financing of tertiary education than the US. In 2001, the EU spent 1.3 % of its GDP on the financing of tertiary education compared to 3.3 % in the US and 1.2 % in Japan. Although public funding of tertiary education is also higher in the US than in the EU, the most striking difference between the two regions concerns private expenditure. In relative terms, private expenditure on higher education is nine times higher in the US than in the EU. The difference between the EU and the US is less marked when one considers all levels of education and is entirely due to private expenditure.

High public spending on education does not necessarily translate into a high level of public spending at the tertiary level. The EU allocated around 21.2 % of total public expenditure on education to tertiary education in 2001 while this share amounted to 29.1 % and 15.1 % in the US and Japan, respectively. Within the EU, Finland, Denmark and Greece, with values above 30 %, had the highest shares of public expenditure on education allocated to tertiary education. Conversely, Italy, Latvia, the UK and France, showed relatively low public support for tertiary education.

Table II.5.2.1 Public and private expenditure on education as % of GDP, 2001

	Tertiary education		All levels of education	
	Public expenditure	Private expenditure	Public expenditure	Private expenditure
Belgium	1.36	0.21	6.11	0.44
Czech Republic	0.80	0.13	4.16	0.41
Denmark	2.73	0.04	8.50	0.28
Germany	1.12	0.09	4.57	0.98
Estonia	1.07	:	5.48	:
Greece	1.19	0.00	3.90	0.23
Spain	1.01	0.30	4.41	0.59
France	1.02	0.16	5.76	0.48
Ireland	1.24	0.20	4.35	0.35
Italy	0.81	0.20	4.98	0.32
Cyprus	1.21	0.79	6.28	1.31
Latvia	0.90	0.54	5.75	0.70
Lithuania	1.34	:	5.92	:
Luxembourg	:	:	3.84	0.001
Hungary	1.11	0.26	5.15	0.57
Malta	0.88	0.02	4.47	0.85
Netherlands	1.32	0.28	4.99	0.45
Austria	1.35	0.06	5.70	0.32
Poland	1.07	:	5.56	:
Portugal	1.09	0.09	5.91	0.09
Slovenia	1.33	0.45	6.13	0.85
Slovakia	0.83	0.05	4.03	0.12
Finland	2.05	0.06	6.24	0.13
Sweden	2.05	0.20	7.31	0.21
UK	0.81	0.30	4.69	0.81
EU-25(1)	1.08	0.20	5.10	0.60
US	1.48	1.77	5.08	2.22
Japan	0.54	0.61	3.57	1.17

Source: DG Research Key Figures 2005
Data: Eurostat
Note: (1) The values for EU-25 are estimations.

Within EU-25, the level of private expenditure on tertiary education remains below 0.5 % of GDP for all Member States with the exceptions of Cyprus (0.8 %) and Latvia (0.5 %). In terms of public expenditure, there are wide differences between the EU Member States. In 2001, the highest-spending countries were the Nordic countries, whose governments spent more than 2 % of GDP on tertiary education, while amongst the lowest-spending countries – Czech Republic, Italy, Malta, Slovakia and the UK – the percentage was between 0.8 % and 0.9 %.

... But inflows of S&E graduates remain relatively high

The supply of human resources is best reflected in the numbers of new university graduates, particularly graduates in Science and Engineering (S&E) and their share in the total number of graduates. In 2003, 24.2 % of all degrees awarded in the EU were in S&E fields of study, a slight decrease from 1998. The corresponding figures for Japan and the US were 23.1 % and 18.5 % respectively. Absolute numbers of graduates are increasing in the EU and the US, particularly in science, but there have been fewer engineering graduates every year in Japan since 1999. Nonetheless, in comparison to the EU and the US, Japan produces a disproportionately high share of engineering graduates (20.1 %) and a remarkably low share of science degrees (3.0 %).

Table II.5.2.2 S&E graduates (ISCED 5 and 6) as % of new degrees, 2003(1)

	Share of new degrees (%)			
	Science	Engineering	Total S&E	Total S&E average annual growth rate (%) 1998-2003(2)
Belgium	9.1	10.2	19.3	0.6
Czech Republic	7.9	16.6	24.5	-0.1
Denmark	8.5	11.3	19.8	0.3
Germany	9.4	17.0	26.4	-1.6
Estonia	7.9	9.3	17.1	-0.9
Greece	:	:	:	:
Spain	11.2	16.9	28.1	5.1
France	13.0	16.4	29.4	-0.9
Ireland	18.0	11.9	29.9	-1.4
Italy	7.6	15.3	22.9	-1.4
Cyprus	9.0	3.1	12.0	-3.8
Latvia	6.3	7.1	13.4	-7.0
Lithuania	5.0	17.4	22.4	-1.9
Luxembourg	10.7	3.8	14.6	-16.8
Hungary	2.9	8.3	11.2	-9.1
Malta	4.1	4.8	8.9	12.5
Netherlands	5.6	10.7	16.3	-0.8
Austria	7.0	21.4	28.4	-3.3
Poland	5.1	9.6	14.6	-0.6
Portugal	6.0	13.0	19.0	1.1
Slovenia	3.4	15.2	18.6	-4.8
Slovakia	8.8	15.3	24.1	2.7
Finland	7.4	21.4	28.7	2.4
Sweden	9.6	20.9	30.5	3.3
UK	17.0	8.8	25.8	-2.9
EU-25(3)	11.0	13.2	24.2	-0.8
US	10.6	7.9	18.5	1.7
Japan	3.0	20.1	23.1	-1.5

Source: DG Research Key Figures 2005
Data: Eurostat
Notes: (1) LU : 2000; IT, FI : 2002.
(2) LU : 1998-2000; IT, FI : 1998-2002; CY : 1999-2003; BE : 2000-2003; UK : 2001-2003.
(3) EU-25 does not include EL, IT, LU and FI.

Within the EU, Sweden, France and Ireland generate the highest shares of S&E graduates. In these countries, S&E degrees account for around one-third of all degrees awarded. Conversely, the proportion of S&E degrees in relation to total degrees is rather low in Malta, Hungary and Cyprus. Since 1998, the proportion of all S&E degrees awarded has declined in no less than 16 Member States and there were only marginal increases in Belgium, Denmark and Portugal. Spain, Sweden, Slovakia and Finland had steady increases and the high rates of growth in Malta and Estonia are largely due to the small size of the graduate populations.

Women are under-represented in research

Although women constitute nearly half of the S&T labour force in the EU, they represent only between 17 % and 35 % of researchers (depending on the sector in which they are employed). As researchers, women are particularly under-represented in the business sector. They are therefore an obvious resource to enlarge the pool of researchers in Europe. Because women have a huge potential for the future of R&D in Europe, many countries – including Finland, Germany and the Netherlands – have undertaken considerable efforts to address this issue.

In almost all countries for which data are available, the share of women (in head count – HC) in all researchers was below 50 % in 2002. The absence of women in R&D activity is particularly noticeable in Germany, where the female share of the population of researchers is about one third below average, and, to a lesser extent, in the Netherlands. This under-representation results from both exogenous (e.g. women-unfriendly working environments, in particular as regards the attractiveness of research careers) and endogenous factors (gender differences in study and career choices, especially vis-à-vis scientific fields).

In the EU, women remain seriously under-represented in the S&E fields of study, especially in engineering where they represent only 22 % of all graduates. The situation in the US is comparable to the EU, whereas in Japan the under-representation is even more dramatic. Among EU Member States, the extent of this under-representation varies greatly. Estonia, Cyprus, Latvia, Lithuania, Poland, Italy and Portugal, as well as the high R&D intensive Sweden, award relatively more S&E degrees to women.

Table II.5.2.3 Female researchers as % of all researchers (HC[1]), 2002[2]

	Business Enterprise	Government	Higher Education
Belgium	18.1	29.9	37.2
Czech Republic	19.7	32.9	34.9
Germany	11.7	23.7	22.4
Denmark	21.3	33.8	32.0
Estonia	23.4	60.0	43.4
Greece	23.9	38.5	38.1
Spain	24.8	42.4	37.0
France	20.9	31.9	33.0
Ireland	20.4	32.1	:
Italy	19.0	38.4	29.8
Cyprus	24.1	32.9	30.5
Latvia	48.2	54.8	52.2
Lithuania	32.7	49.2	48.0
Luxembourg	:	33.5	20.4
Hungary	23.7	38.2	35.3
Malta	:	51.5	:
Netherlands	9.3	:	27.3
Austria	:	:	:
Poland	28.2	42.9	38.9
Portugal	27.7	56.1	45.1
Slovenia	28.7	43.3	34.3
Slovakia	29.9	44.1	40.8
Finland	18.4	40.7	44.2
Sweden	25.1	:	39.9
UK	:	31.8	36.6
EU-25[3]	17.5	34.8	34.9
US	:	:	:
Japan	6.0	11.5	20.0

Source: DG Research Key Figures 2005
Data: Eurostat, WIS database
Notes: (1) FTE instead of HC : BE - Government, Higher Education; DE - All sectors; IE : Government.
(2) Business Enterprise - PL : 2000; BE, DE, EL, IE, IT, LU, NL, PT, SE : 2001. Government - BE, EL, PT : 2001.
Higher Education - IE : 2000; BE, DE, EL, IT, LU, NL, PL, PT, SE : 2001.
(3) The values for EU-25 were calculated by DG Research.

Table II.5.2.4 Female graduates (ISCED 5 and 6) as % of all graduates in S&E fields of study, 2003[1]

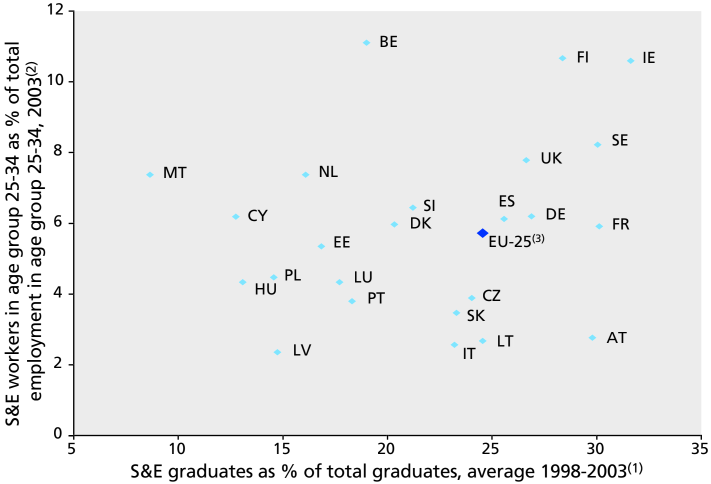
	Science	Engineering
Belgium	31.7	19.3
Czech Republic	38.7	24.7
Denmark	30.6	30.1
Germany	34.9	17.2
Estonia	44.6	40.8
Greece	:	:
Spain	37.7	25.6
France	41.0	21.7
Ireland	45.3	18.7
Italy	52.9	27.2
Cyprus	47.2	26.5
Latvia	46.8	29.9
Lithuania	47.8	32.2
Luxembourg	4.2	1.9
Hungary	33.2	24.3
Malta	35.7	18.4
Netherlands	29.3	12.8
Austria	33.8	16.9
Poland	51.0	23.8
Portugal	58.2	33.9
Slovenia	39.3	22.4
Slovakia	41.2	30.5
Finland	48.5	20.5
Sweden	46.4	28.6
UK	42.2	19.2
EU-25[2]	41.0	22.1
US	41.4	19.2
Japan	25.6	12.7

Source:DG Research Key Figures 2005
Data:Eurostat
Notes: (1) LU : 1998; IT, FI : 2002.
(2) EU-25 does not include EL, IT, LU and FI.

Improving the attractiveness of research careers

Making research careers more attractive is crucial to increasing the inflow of S&E educated people into research positions and S&E occupations. Comparing the proportion of S&E graduates in the total number of graduates (supply side) with the number of Scientists and Engineers (S&E workers) aged 25-34 as a proportion of total employment of the same age (demand side) therefore helps to examine to what extent S&E educated people actually enter an S&E career in their country.

Figure II.5.2.1 Inflow of S&E graduates into S&E occupations, 1998-2003



Source: DG Research Key Figures 2005
Data: Eurostat
Notes: (1) LU : 1998-2000; IT, NL, FI : 1998-2002; CY : 1999-2003; BE : 2000-2003; UK : 2001-2003.
(2) LU : 2000; IT, NL, FI : 2002.
(3) EU-25 was estimated by DG Research and does not include EL and LU.

Most of the new Member States, as well as Italy, Portugal and Austria produce average to high shares of S&E graduates, but have relatively low levels of Scientists and Engineers in their active populations, indicating that a non-negligible share of their S&E graduates opt for a non S&E career or for a job outside the country. These countries are characterised by relatively low R&D intensities and a relatively weak contribution by the business sector to R&D funding. Conversely, Finland, Ireland, Belgium, and to a lesser extent Sweden, are able to combine an average to high level of S&E graduates with a high level of S&E workers in their active population. In particular, Belgium seems quite successful at attracting S&E educated people into S&E positions. These countries generally combine high overall R&D intensities with a higher involvement of the business sector in the funding of R&D.

Beyond the characteristics and structure of the domestic economy, another factor is international migration flows. About 11 % of the doctorates in Science and Engineering awarded to non-US citizens in the US, are awarded to European PhD students, and this share has been growing since the late nineties. Nearly 60 % of this group have firm plans to stay in the US after their PhD instead of returning to their country of origin. Moreover, that proportion has increased significantly over the past decade: from 44.5 % at the beginning of the 1990s to 57.5 % at the turn of the millennium. This increase is particularly striking for French recipients of US S&E doctorates, almost half of whom now accept a post-doctoral research appointment or academic, industrial or other employment in the US after their PhD, compared to around 30 % ten years ago.

Europe does not succeed in retaining the best researchers. At the same time, Europe appears to hold much less of an attraction notably to US researchers while being a popular destination for scientists from the developing countries[15].

Table II.5.2.5 Non-US citizens awarded doctorates in the sciences and in engineering, by country of citizenship and year of doctorate, 1997-2002

Country	Percentage of total foreign citizenship		
	1997	2002	Average annual growth rates 1997-2002 %
Total foreign citizenship	**100**	**100**	**-2.0**
Europe, total	**13.0**	**17.5**	**6.1**
EU-25	**9.3**	**10.7**	**2.8**
Belgium	0.2	0.2	0.8
UK	0.9	1.5	10.5
France	0.7	1.0	6.7
Germany	1.8	2.2	4.2
Europe, other	9.4	12.5	6.0
North America	**4.7**	**6.5**	**6.5**
South America	**4.0**	**4.7**	**3.3**
East Asia	**46.6**	**48.4**	**0.8**
West Asia	**19.6**	**16.8**	**-3.0**
Pacifica / Australasia	**2.0**	**1.7**	**-2.7**
Africa	**3.4**	**3.3**	**-0.5**
Country unknown	**6.7**	**1.0**	**-31.0**

Source:DG Research Key Figures 2005
Data: National Science Foundation, Division of Science Resources Statistics, Survey of Earned Doctorates

15. Third European Report on Science and Technology Indicators 2003, p. 224.

Table II.5.2.6 Firm plans of foreign recipients of United States S&E doctorates to stay in the United States, by place of origin

Place of origin	Firm plans to stay		
	% share of foreign S&E doctorate recipients(1)		
	1990–93	1994–97	1998–2001
All non-US citizens	**40.9**	**43.3**	**54.1**
Europe	**44.5**	**47.9**	**57.5**
Greece	45.8	40.8	56.5
UK	57.7	59.5	62.4
Germany	43.0	44.6	52.4
Italy	36.5	31.9	49.8
France	29.4	32.0	48.4
Spain	38.5	45.7	40.8
Other	45.4	53.0	61.1
East / South Asia	**44.1**	**46.2**	**58.5**
Pacifica / Australasia	**33.1**	**28.7**	**43.1**
North / South America	**36.0**	**36.1**	**42.4**
Africa	**24.5**	**25.8**	**40.7**

Source:DG Research Key Figures 2005
Data: NSF
Notes: (1) Data include foreign doctoral recipients who are either permanent or temporary residents. Recipients with firm plans to stay have a post-doctoral research appointment or academic, industrial or other firm employment in the United States.

Part III – Performance of the Knowledge-based Economy

III-1. Introduction

The aim of countries to maintain and develop their scientific and technological knowledge-bases, has led to an increasing focus on a number of indicators. These indicators relate to important questions such as: What is the share of knowledge-based industries in country x? What is the importance of a country in the overall production of scientific publications? What is the country's share of patents? These, among other indicators, capture the changing relationships between science and technology.

A country's performance in the knowledge-based economy is not measured simply by outputs of science and technology, but must also be judged in relation to the important goal of increasing its competitiveness. Indeed these different aspects of performance are closely linked. A competitive economy is increasingly understood as an economy able to achieve sustained rises in standards of living for its population at low levels of unemployment. The key determinant of competitiveness is labour productivity. Gains in labour productivity are the result of increasing human capital, capital deepening and technical progress or innovation as measured by total factor productivity. The degree of innovativeness is determined by firms' own R&D activities leading to new products or processes and by spill-over effects that magnify the benefits of own R&D efforts, but also by diffusion effects associated with imported technology and the presence of multinational firms.

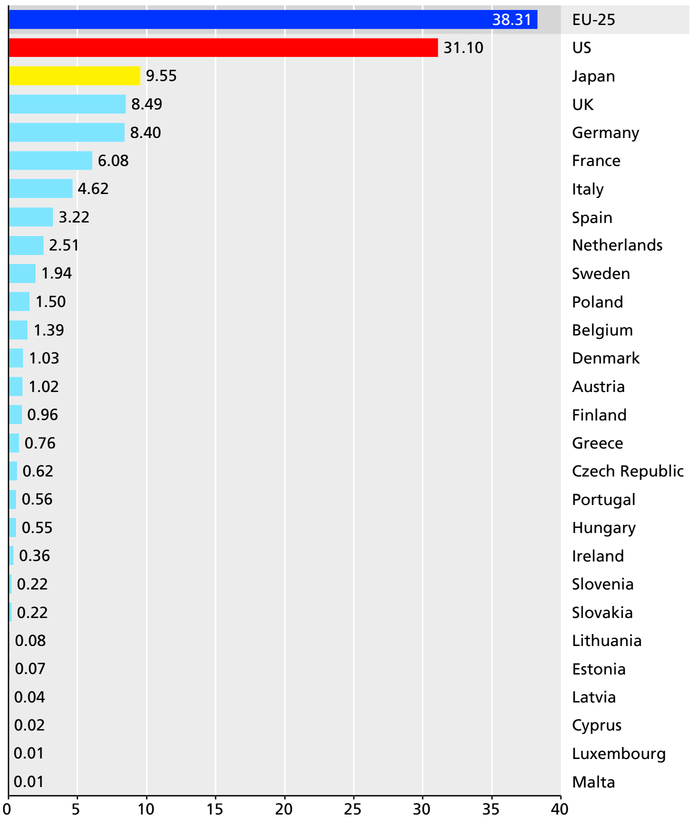
Part III analyses the performance of European economies in their transition towards a knowledge-based economy from two perspectives. Firstly, the performance of the EU, the US, Japan and the individual EU Member States is examined in terms of scientific and technological output. Secondly, the performance of European industries is analysed in terms of international trade and productivity growth and compared to the US and Japan.

III-2. S&T output

The EU leads in scientific output

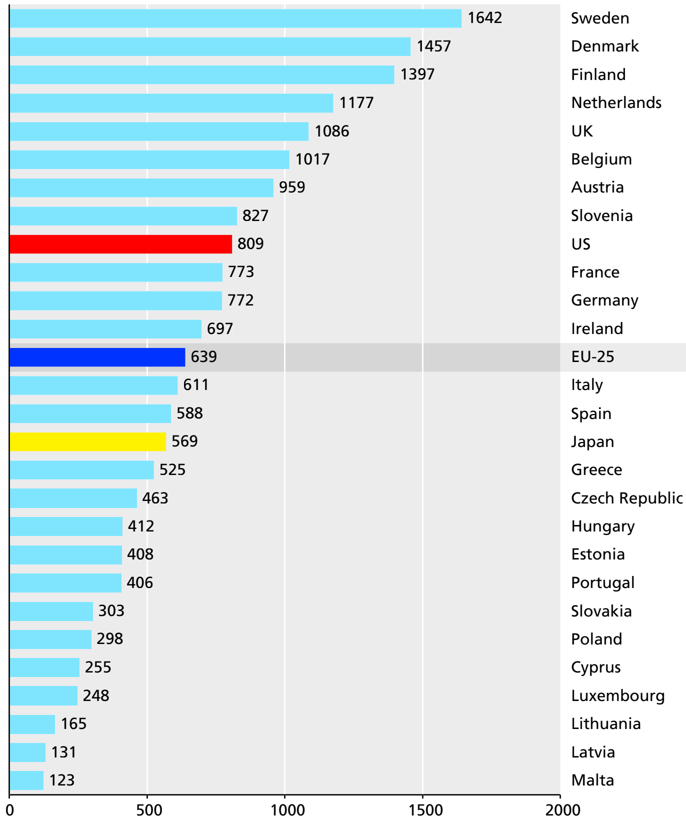
In terms of total number of publications as well as world share, the EU maintained a comfortable lead. Its world share in 2003 was 38.3 % (showing a slight decline compared to 1997) whereas the US was responsible for 31.1 % of world scientific publication output. Japan, for its part, accounted for 9.6 % of world scientific publications. Among individual EU Member States, the UK, Germany, France and Italy were the largest producers of scientific publications, with an aggregated world share amounting to 27.6 %. These four countries accounted for more than 70 % of the EU's scientific publication output in 2003.

Figure III.2.1 World shares of scientific publications (%), 2003



Source: DG Research
Key Figures 2005
Data: Thomson Scientific/CWTS, Leiden University (fractional counting method has been used).

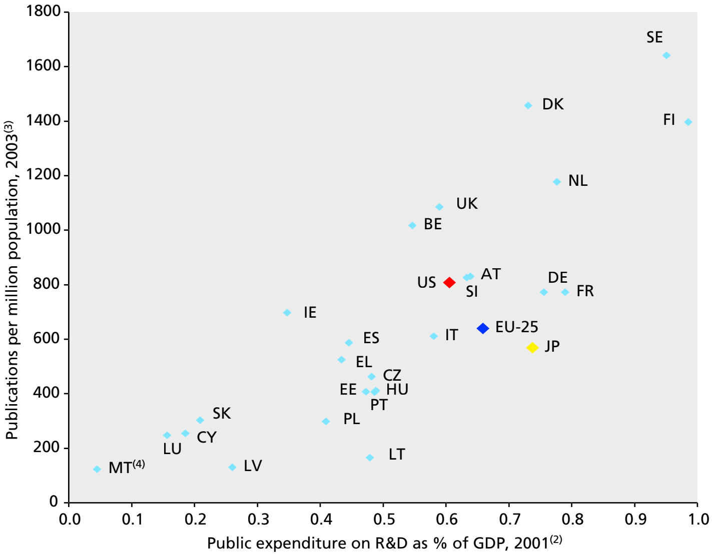
Figure III.2.2 Number of scientific publications per million population, 2003



Source: DG Research
Key Figures 2005
Data: Thomson Scientific/CWTS, Leiden University; OECD, Eurostat
Note: Population for US and JP was estimated.

Comparing Europe, the US and Japan in terms of the number of scientific publications per million population, the US leads with 809, followed by Europe with 639 and Japan with 569. Within Europe, the ratio is particularly high in the three Nordic countries. The new Member States can be found at the lowest end of the scale, except for Slovenia which is well above the EU average.

Figure III.2.3 Publications in relation to public expenditure on R&D(1)



Source: DG Research Key Figures 2005
Data: Eurostat, OECD, Thomson Scientific/CWTS, Leiden University
Notes: (1) In order to take into account of the gap between R&D input and scientific output, a two-year lag between public expenditure on R&D and publications per million population has been applied.
(2) MT : 2002; AT : 1998.
(3) AT : 2000.
(4) MT : Public expenditure on R&D does not include higher education expenditure on R&D.

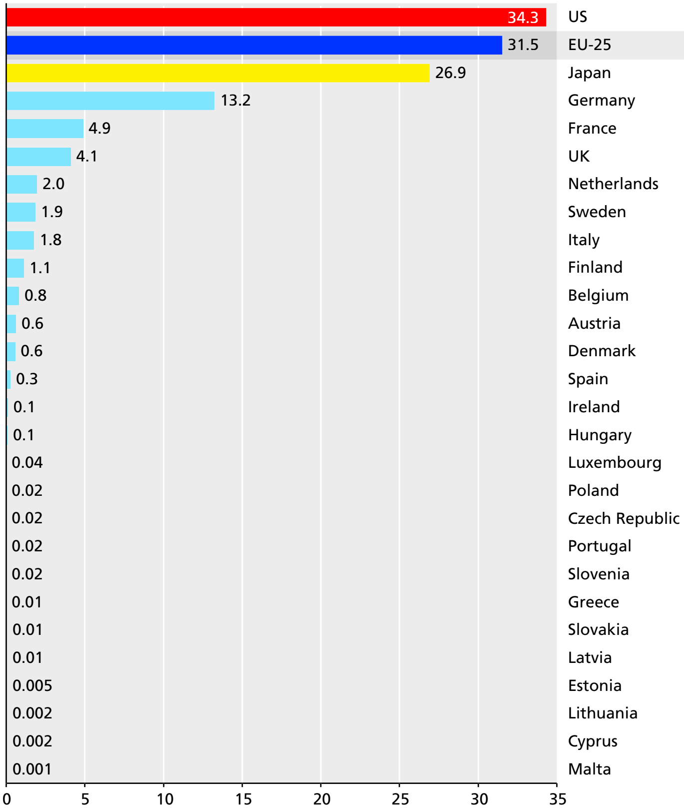
There is a strong positive relationship between the level of public expenditure on R&D relative to GDP and the number of scientific publications per million population across the EU countries, the US and Japan.

But the EU is failing to fully exploit its scientific base

Triadic patent families refer to patent inventions for which protection has been sought at the three major patent offices: the European Patent Office (EPO), the US Patent and Trademark Office (USPTO) and the Japanese patent office (JPO). The extra protection is generally assumed to imply higher commercial returns. Furthermore, this measure irons out any bias in the output indicators introduced by patents that are only sought in their own region or by double-counting at the global level. They therefore provide a useful proxy for global technological output.

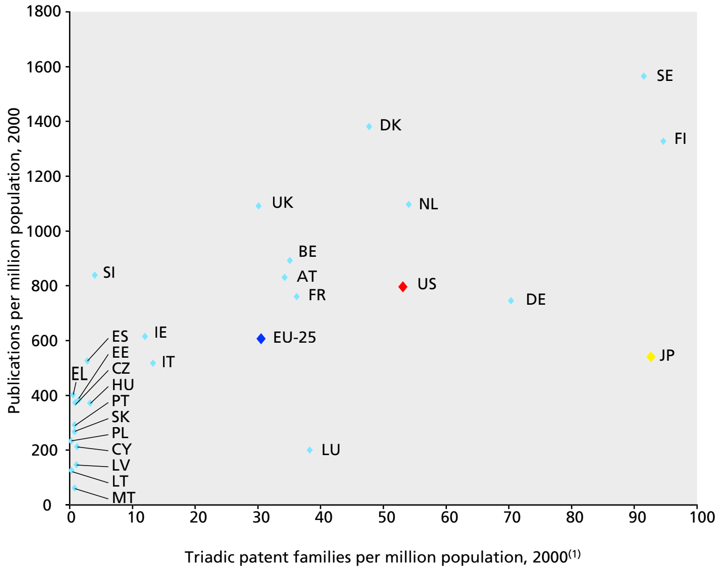
The US (34.3 %) and EU-25 (31.5 %) accounted for nearly two thirds of triadic patent families in 2000. Japan accounted for a further 26.9 %, implying that Europe and its two main competitors dominate global technological output. However, only Japan increased its world share in technological output during the period 1997-2000. Within the EU, Germany has a world share of 13.2 % of triadic patent families, more than the shares jointly held by France, the UK, Sweden and Italy, but nevertheless a slight decline on its share in 1997. France and Sweden's world shares have also decreased over the same period, but the UK, Italy and Finland experienced increases.

Figure III.2.4 World shares in total triadic patent families (%), 2000(1)



Source: DG Research Key Figures 2005
Data: OECD
Notes: (1) Data by earliest priority date and country of residence of the inventors (fractional counting).

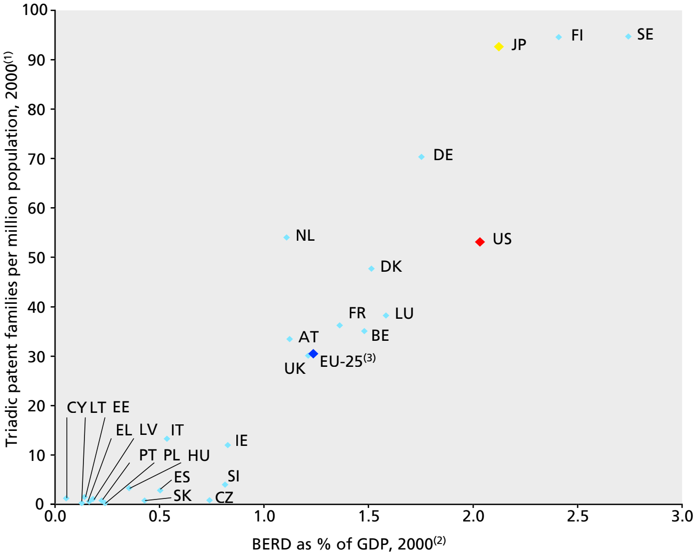
Figure III.2.5 Triadic patent families and publications per million population, 2000



Source: DG Research Key Figures 2005
Data: Eurostat, OECD, Thomson Scientific/CWTS, Leiden University
Notes: (1) Data by earliest priority date and country of residence of the inventors.

When technological output is standardised by population size, a different picture emerges. Japan has the highest number of patents in total triadic patent families per million population (93) followed by the US (53) and EU-25 (31). In Europe, only Finland and Sweden can keep pace with Japan. Germany and the Netherlands outperform the US. In contrast, no less than 13 Member States were producing less than five triadic patents per million population in 2000.

Figure III.2.6 Triadic patent families(1) in relation to BERD as % of GDP



Source: DG Research
Data: Eurostat, OECD
Notes: (1) Data by earliest priority date and country of residence of the inventors.
(2) AT : 1998; SE : 1999.
(3) EU-25 does not include MT.

Key Figures 2005

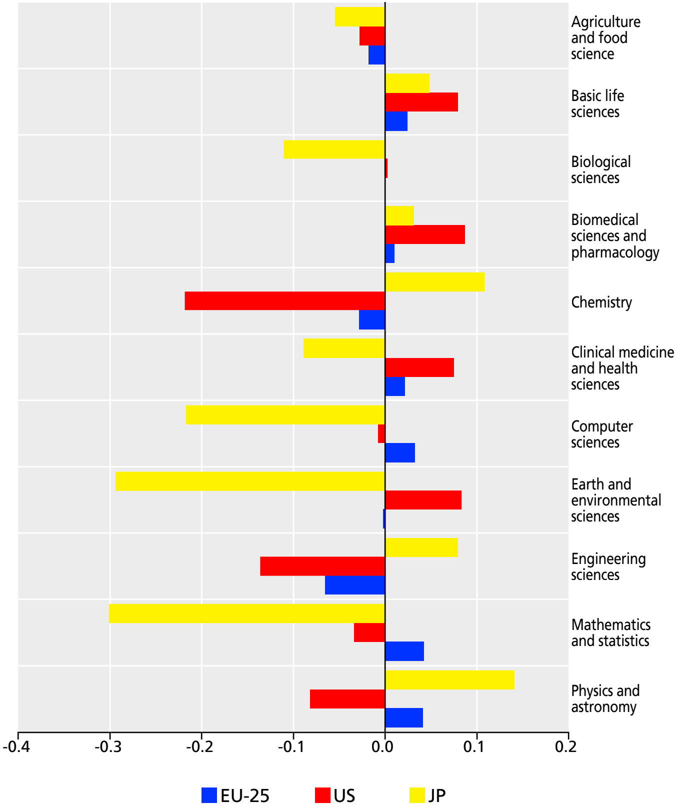
Countries with high levels of business R&D expenditure relative to GDP such as Finland, Sweden and Japan also have large numbers of triadic patent families per million population. In contrast, countries such as the new Member States show both low business R&D intensities and low numbers of triadic patent families per million population.

S&T knowledge bases are highly diversified in several EU countries

In order to assess the relative scientific and technological strengths and weaknesses of regions and countries, it is useful to examine their scientific and technological specialisations. A region/country's level of specialisation in a given field of science or technology is measured by comparing the world share of the region/country in the particular field to the world share of the region/country for all fields combined (we refer to the 'share of scientific publications' for scientific specialisation patterns, and to the 'share of patents' for technological specialisation). The EU's scientific and technological output appears to be more diversified than that of the US. Although this is a potentially rich resource in the medium and long term, additional efforts are required to ensure that activities are not too fragmented.

Compared to the US and Japan, the scientific capabilities of the EU are distributed evenly across all fields of science. The EU shows no strong specialisation or under-specialisation in any particular field. Conversely, the US is under-specialised in chemistry and engineering sciences; Japan specialises in physics and astronomy but is less active in biological sciences, computer sciences, earth and environmental sciences, and mathematics and statistics.

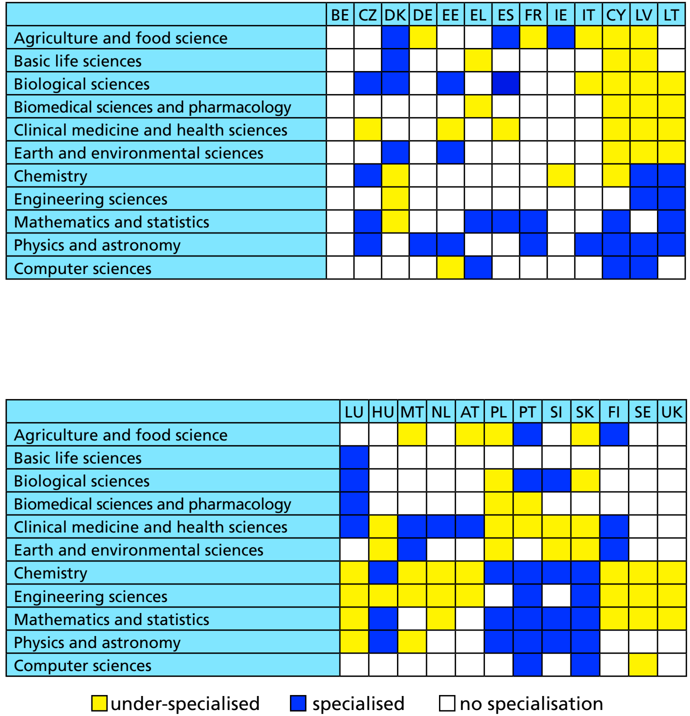
Figure III.2.7 Scientific publications - relative specialisation index, 2000-2003 EU-25, US, Japan



Source: DG Research
Data: Thomson Scientific/CWTS, Leiden University

Key Figures 2005

Figure III.2.8 Scientific publications - relative specialisation index, 2000-2003 – EU Member States



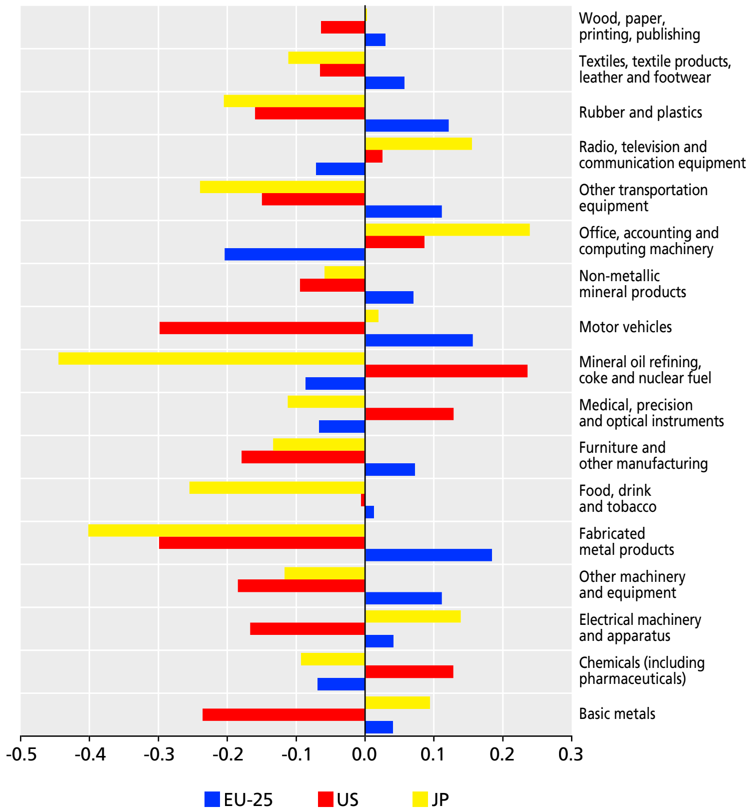
Source: DG Research
Data: Thomson Scientific/CWTS, Leiden University

Key Figures 2005

The EU countries show diversity with regards to their scientific capabilities. Among the most active publishing EU countries, Germany is strong in physics and astronomy but is less involved in agriculture and food science; the UK is relatively under-specialised in chemistry, engineering sciences, and mathematics and statistics; France is active in mathematics and statistics as well as in physics and astronomy but is weak in agriculture and food science; finally, Italy shows under-specialisation in agriculture and food science and in biological sciences. With regard to the smaller (in terms of publications) EU countries such as Portugal and Slovakia, concerns may arise about the broad scope of their scientific efforts given the constraints imposed by their limited financial and human resources.

Compared to the US and Japan, the EU shows a technological specialisation in traditional manufacturing industries. Over the period 1997-2000, the EU specialised mostly in rubber and plastics, transportation equipment and motor vehicles, fabricated metal products, and other machinery and equipment, whereas an under-specialisation in ICT manufacturing industries is revealed[16]. The US specialised mainly in ICT manufacturing industries and chemical-related industries. Japan primarily focused on electrical machinery and apparatus and ICT manufacturing.

Figure III.2.9 EPO patent applications in the manufacturing sector - relative specialisation index, 1997-2000 EU-25, US, Japan



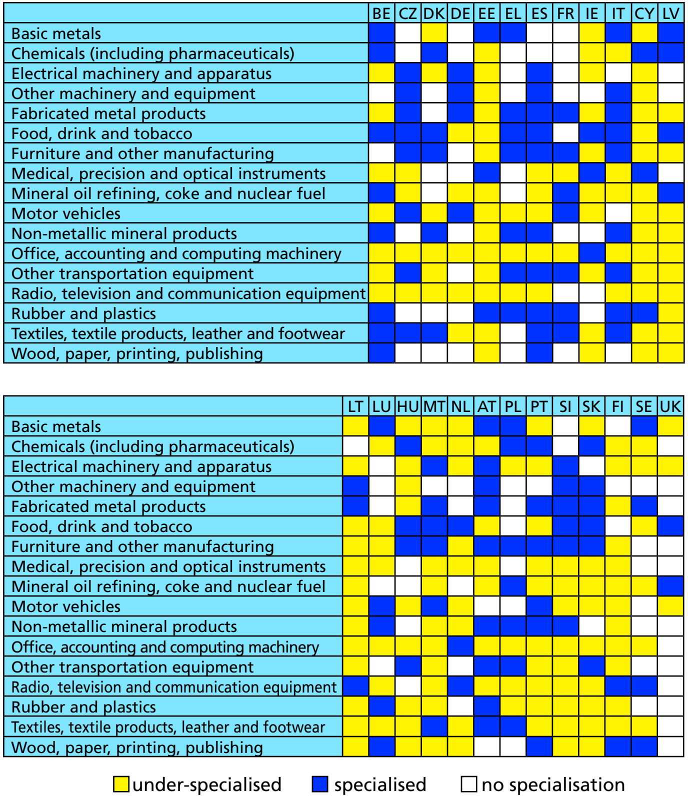
Source: DG Research Key Figures 2005

Data: OECD

Note: Data by earliest priority date and country of residence of the inventors.

16. "ICT manufacturing industries" refer to the following sectors: radio, television and communication equipment; office, accounting and computing machinery; medical, precision and optical instruments.

Figure III.2.10 EPO patent applications in the manufacturing sector - relative specialisation index, 1997-2000 – EU Member States



Source: DG Research
Key Figures 2005
Data: Thomson Scientific/CWTS, Leiden University
Note: Data by earliest priority date and country of residence of the inventors.

Technological specialisation is very diverse within the EU pointing to fragmented R&D efforts in Europe. Most of the new Member States have highly dissimilar specialisation profiles vis-à-vis the other EU countries. These country divergences reveal in part substantial differences in industry structure.

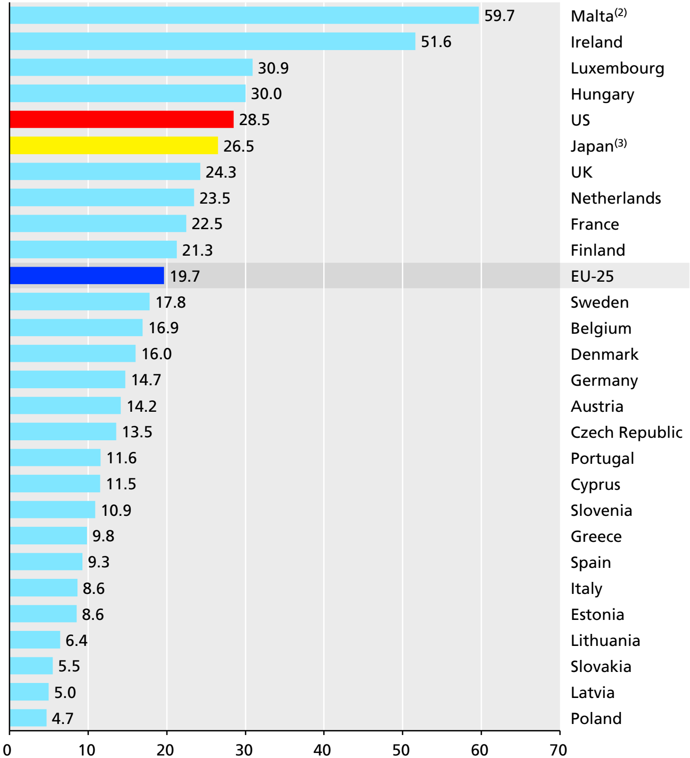
The degree of technological diversification varies sharply across the EU Member States and does not seem too dependent on their levels of R&D effort. Some of the EU countries with low levels of R&D expenditure – including Czech Republic, Greece, Poland, and Spain – exhibit high diversification which may impede their performance.

III-3. Industry, technology and competitiveness

Manufacturing exports are less technology-intensive in the EU than in the US and Japan

The relative strengths of European industry can be assessed by its ability to produce goods that find demand in the global marketplace. European competitiveness can therefore be gauged by examining trends in the market shares of EU high-tech industries in international trade.

Figure III.3.1 High-tech manufacturing industries - exports as % of total manufacturing exports, 2003(1)

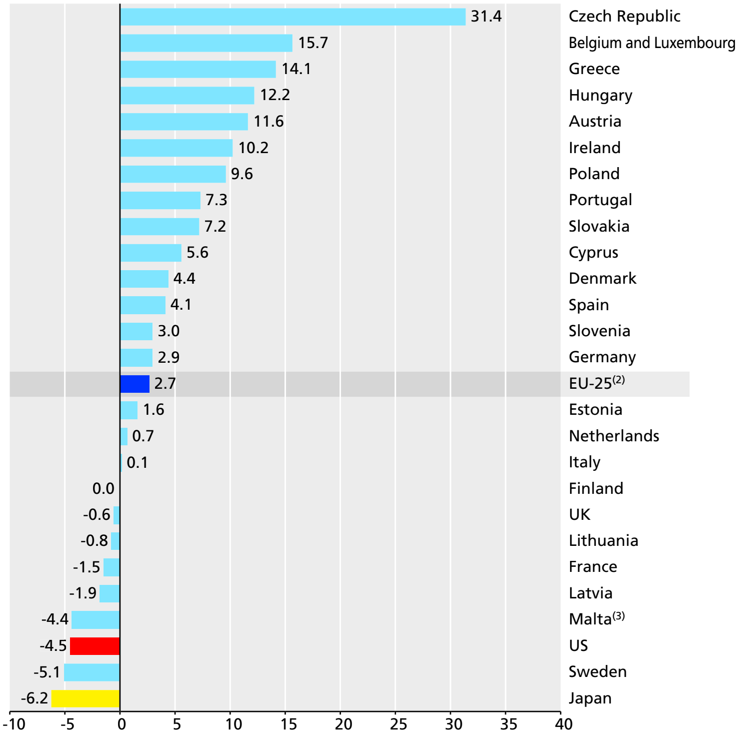


Source: DG Research Key Figures 2005
Data: Eurostat (Comext), UN (Comtrade)
Notes: (1) The value for EU-25 does not inlcude intra-EU-25 exports.
(2) Data for MT refer to 2001.
(3) Data for JP refer to 2002.

In 2003, manufacturing exports were less technology intensive in the EU than in the US and Japan. High-tech industries accounted for about 20% of total EU manufacturing exports, while they represented more than 25% of total manufacturing exports in Japan and the US. Within the EU, manufacturing exports are largely technology intensive for Malta, Ireland, Luxembourg and Hungary, where high-tech industries accounted for more than 30% of total manufacturing exports. The extremely high scores of small-scale economies such as Malta and Ireland, and to a lesser extent of Luxembourg and Hungary, may be due to the presence of a few large, export-led and technology-intensive companies. However, their share was particularly low in most of the other new Member States and southern European countries., where high-tech industries accounted for more than 30% of total manufacturing exports.

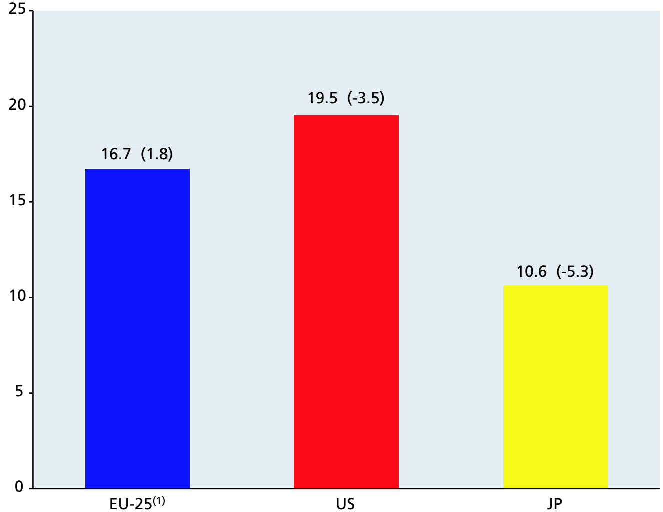
In 2002, US high-tech industries accounted for more exports at world level than the EU or Japan, i.e. nearly 20 % in comparison to 16.7 % and 10.6 %, respectively. However, the world export share of EU high-tech industries increased by 1.8 % annually from 1997 to 2002, whereas the shares of Japan and the US followed downward trends. The positive trend in Europe seems primarily due to the development of high-tech production in the new Member States, a positive effect of enlargement, which also has positive spill-overs for older Member States, which are all out-performing the US with the exception of Sweden. Not surprisingly, the EU countries with the highest R&D expenditure – namely the UK, Germany and France – had high world export shares for their high-tech sectors. Nonetheless, a few smaller European countries such as the Netherlands, Ireland and Belgium also accounted for a healthy share in world high-tech exports. Moreover, over the period 1997-2002, the most significant growth in high-tech manufacturing exports was experienced by several medium-sized countries with average R&D intensity.

Figure III.3.2 High-tech manufacturing industries - world market shares of exports - average annual growth (%), 1997-2002(1)



Source: DG Research Key Figures 2005
Data: Eurostat (Comext), UN (Comtrade)
Notes: (1) All data include intra-EU-25 high-tech exports and the world market refers to total world high-tech exports including intra-EU-25 exports.
(2) EU-25 does not include MT.
(3) Data for MT refer to 1996-2001.

Figure III.3.3 High-tech manufacturing industries - world market shares of exports excluding intra-EU-25 trade (%), 2002; in brackets: average annual growth rates, 1997-2002



Source: DG Research Key Figures 2005
Data: Eurostat (Comext), UN (Comtrade)
Notes: (1) EU-25 does not include MT.

While the US and Japan have a structural trade surplus in high-tech manufacturing industries, the EU is characterized by a structural trade deficit in these industries. Within the EU, only Malta, Ireland, Finland, the UK, Sweden, Slovenia and to a lesser extent France have a structural trade surplus in high-tech manufacturing industries in 2003. However, the situation in most of the other Member States has improved since 1997.

The EU-US R&D investment gap at the sectoral level

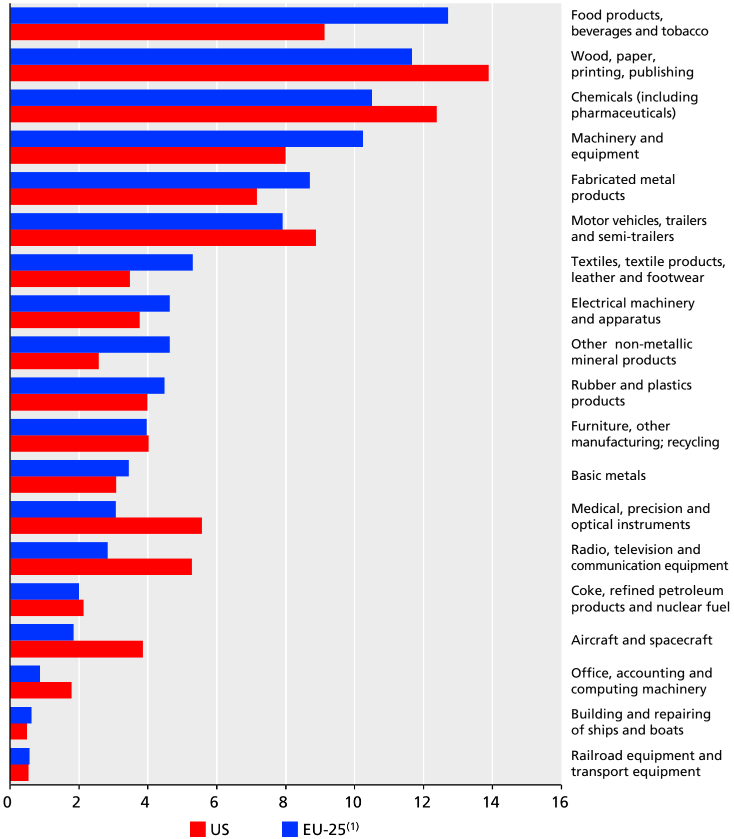
There is an R&D investment gap between EU-25 and the US. In 2003, total business R&D intensity amounted to 1.23 % in the EU compared to 1.78 % in the US. The business sector accounts for more than half of the R&D activity in the EU and the US economies and is responsible for about 80 % of the R&D investment gap between the two regions. This difference in aggregated business R&D intensity between the EU and the US can be explained by two major factors: 1) the weight of the sectors in total value added (industry structure) and 2) the sector-specific business R&D intensities.

In terms of industry structure, the service industries as a whole[17] contribute to around three quarters of total output in the US and the EU. In 2002, their share in total value added amounted to 76.7 % in the US and 70.7 % in the EU compared to 73.1 % and 68.3 %, respectively, in 1997. The share of ICT manufacturing industries[18] in manufacturing output is much bigger in the US than in the EU. These industries contributed to 12.6 % of manufacturing value added in the US in 2002, while their share amounted to only 6.8 % in the EU.

17. Services cover the following activities: wholesale and retail trade, restaurants and hotels; transport and storage and communication; finance, insurance, real estate and business services; community social and personal services.

18. ICT manufacturing industries refer to the following sectors: radio, television and communication equipment; office, accounting and computing machinery; medical, precision and optical instruments.

Figure III.3.4 Manufacturing value added - % distribution by sector, 2002



Source: DG Research Key Figures 2005

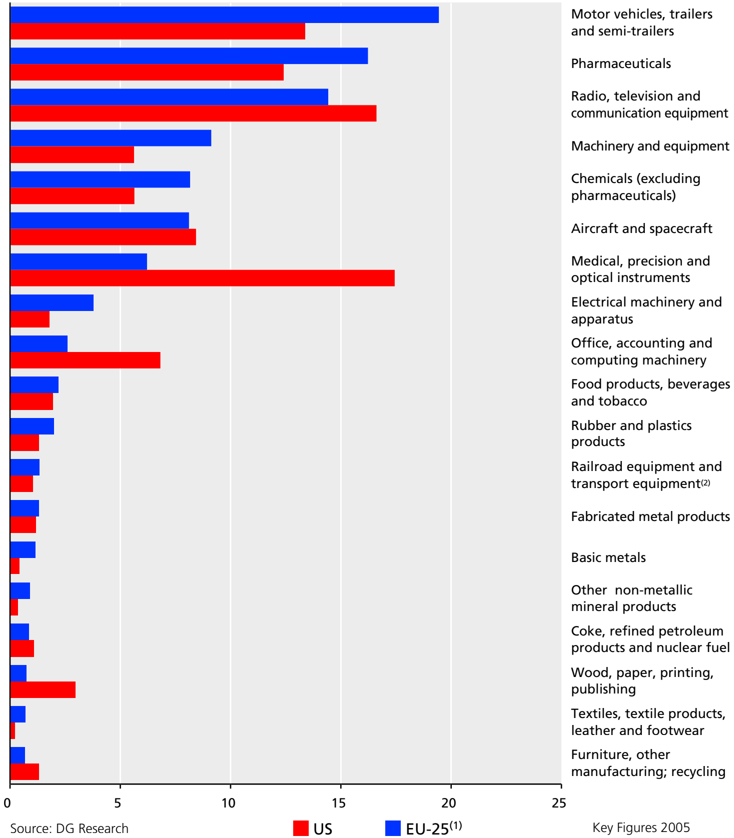
Data: Groningen Growth and Development Centre

Notes: (1) EU-25 does not include EE, CY, LV, LT, MT, SI.

The total services sector accounts for one third of total business R&D in the US, in contrast to less than one fifth in the EU. The share of services in total business R&D was 39.1 % in the US in 2002, a substantial increase on its level of 19.7 % in 1997. The corresponding share for the EU was 15.1 % in 2002 compared to 11.4 % in 1997. The large and increasing share of business R&D expenditure on services, especially in the US and the EU, is mainly due to three factors:

1. an improvement of the measurement of services sector R&D[19];
2. a growth in R&D intensity in the services sector;
3. a strengthening of R&D out-sourcing in both the business and government sectors[20].

Figure III.3.5 Manufacturing BERD - % distribution by sector, 2002



Source: DG Research Key Figures 2005
Data: OECD, Eurostat
Notes: (1) EU-25 does not include EE, EL, IE, LT, LU, AT, PT, SK.
(2) Building and repairing of ships and boats is included in Railroad equipment and transport equipment.

19. It is important to note that R&D at industry level in general is difficult to measure because R&D surveys are conducted at enterprise level and large R&D intensive firms such as IBM are classified according to their "primary activity", which is based on employment. IBM switched from being a manufacturing company in 1992 to being a services company. Thus, the share of services in total business R&D is overestimated in the case of the US. Many more services in the EU than in the US are provided by the public sector.
20. Services sector R&D, which for some countries can be significant, is for other countries in reality, outsourced manufacturing R&D.

In contrast to the EU, R&D performed by the manufacturing sector in the US is heavily concentrated in ICT manufacturing industries. The share of these industries in US manufacturing R&D was 40.9 % in 2002, well above the 23.2 % level in the EU. This gap was mainly due to the 'medical, precision and optical instruments' industry, which in 2002 had a share of 6.2 % of total manufacturing R&D in the EU compared to 17.4 % in the US. The US also performed, in relative terms, more R&D than the EU in the 'wood, paper, printing, and publishing' industries. On the other hand, the EU had significantly higher shares of manufacturing R&D than the US in the 'chemicals', 'pharmaceuticals', 'machinery and equipment', and 'motor vehicles, trailers and semi-trailers' industries.

In order to investigate to what extent industry structure is likely to impact on total business R&D intensity, we have re-calculated, by means of a basic simulation exercise, the business R&D intensity at EU level using the US industrial structure. Assuming that the EU[21] had the same industrial structure as the US in 2002 (the latest year available for such a comparison) and keeping the EU business R&D intensities unchanged at sector level, the total business R&D intensity (aggregated business R&D as a percentage of aggregated value added in each sector) at EU level would decrease slightly from 1.40 % to 1.39 %, well below the US value of 1.97 %.

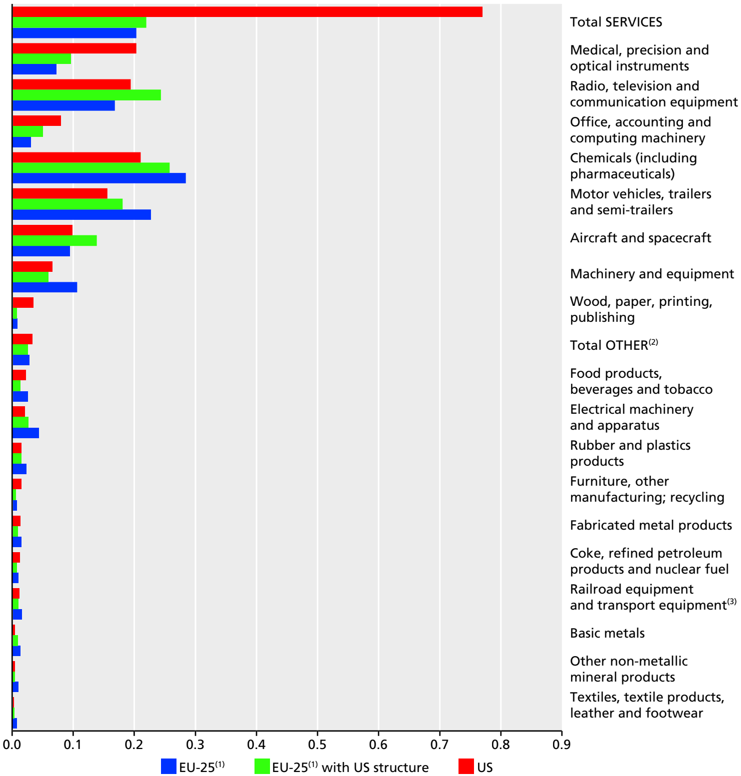
Admittedly, the conclusion of this basic simulation exercise should be interpreted with caution since it supposes, notably, that: i) the US industrial structure is not correlated to the distribution of R&D expenditure across the business sector; ii) the interactions between manufacturing and services with respect to R&D activity are the same in the EU and in the US; and iii) measurement problems in the services sector in the EU and the US are not considered. However, such an exercise has the advantage of stressing the critical importance of R&D in the service sector and its contribution to overall business R&D intensity.

Assuming that the EU had the same industrial structure as the US, the most significant increase in the contribution of industries to total business R&D intensity in the EU would originate from the following sectors (in decreasing order of importance): 'radio, television and communication equipment'; 'aircraft and spacecraft'; 'medical, precision and optical instruments'; 'office, accounting and computing machinery'; and 'total services'. In particular, the contribution of the ICT manufacturing industries would rise from 0.27 to 0.39 percentage points, which would compare to 0.48 percentage points in the US. On the other hand, the contributions of several industries – especially 'machinery and equipment', 'motor vehicles, trailers and semi-trailers', and 'chemicals' - to total business R&D intensity in the EU would decline.

Most of the EU-US R&D gap, therefore, stems from a low R&D intensive services sector, as well as, to a lesser extent, a smaller size and lower R&D intensity in the ICT manufacturing sector. In the US, the services sector contributes approximately 0.8 percentage points of total business R&D intensity, which is much higher than in the EU (where it accounts for 0.2 percentage points of total business R&D intensity).

21. In order to ensure comparability between the EU and the US in terms of value added and R&D expenditure at industry level, the EU refers to the following Member States: BE, CZ, DK, DE, ES, FR, IT, HU, NL, PL, FI, SE and UK. These countries account for the bulk of R&D effort in EU-25.

Figure III.3.6 Industry contributions to total business R&D intensity in the US and EU-25(1), 2002 in percentage points



Source: DG Research Key Figures 2005
Data: Eurostat, OECD, Groningen Growth and Development Centre
Notes: (1) EU-25 does not include EE, EL, IE, CY, LT, LV, LU, MT, AT, PT, SI, SK.
(2) OTHER consists of the following sectors: Agriculture; Forestry; Fishing; Mining and quarrying; Electricity, gas and water supply; Construction.
(3) Building and repairing of ships and boats is included in railroad equipment and transport equipment.

Figure III.3.7 Business R&D intensity by sector, 2002

Source: DG Research Key Figures 2005
Data: Eurostat, OECD, Groningen Growth and Development Centre
Notes: (1) EU-25 does not include EE, EL, IE, CY, LT, LV, LU, MT, AT, PT, SI, SK.
(2) Building and repairing of ships and boats is included in Railroad equipment and transport equipment.
(3) OTHER consists of the following sectors: Agriculture; Forestry; Fishing; Mining and quarrying; Electricity, gas and water supply; Construction.

Although both the interactions between manufacturing and services and the measurement of R&D activity in those sectors may differ in the US and the EU, these results tend to show, in line with other studies, the huge potential of services in contributing to overall business R&D intensity and consequently the need to adapt R&D policy to the growing importance of services R&D[22]. Further studies on R&D in the services sector are nonetheless required in order to tailor R&D policy to the needs of this sector.

ICT diffusion in Europe and the US: explanation of the productivity growth gap?

The remarkable acceleration in labour productivity growth and multifactor productivity growth in the US since the mid 1990s has been extensively discussed over recent years. A general consensus has emerged that this acceleration can be attributed to information and communication technology (ICT), suggesting that the 'Solow paradox' ("we see computers everywhere but in the productivity statistics") has largely been resolved.

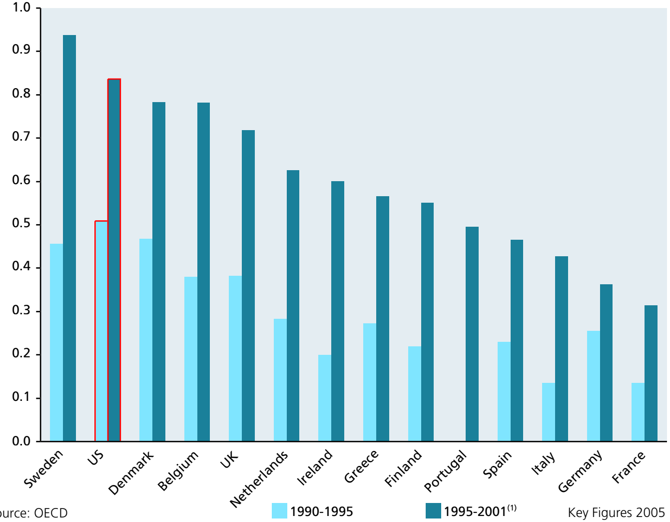
Empirical studies at aggregate, industry, and firm-level stress three effects of ICT on economic growth and productivity.

Capital deepening

Investment in ICT can contribute to capital deepening by adding to the stock of capital that is available for workers and consequently helps raise labour productivity and growth.

ICT investment accounted for between 0.3 and 1.0 percentage points of annual average GDP growth during 1995-2002 in the EU countries (for which data are available) and the US. The contribution of ICT investment to GDP growth was highest in Sweden, the US, Denmark and Belgium while France, Germany and Italy were lagging behind.

Figure III.3.8 Contribution of ICT investment to GDP growth in selected EU countries and the US in percentage points



Source: OECD
Key Figures 2005
Data: OECD
Notes: (1) DE, FR, US, JP : 1995-2002.

22. OECD (2005), *Enhancing the Performance of the Services sector,* OECD: Paris; OECD (2004), Science, Technology and Industry Outlook, OECD: Paris; OECD (2001), Innovation and Productivity in Services, OECD: Paris.

Increased productivity in the ICT-producing sector

Rapid technical change in the production of ICT goods and services can contribute to acceleration in labour productivity growth in the ICT-producing sector since a decline in the prices of these goods can lead to higher growth in real volumes. Moreover, since ICT goods are part of output, rapid technical change in the production of ICT goods can raise the growth rate of multifactor productivity, thus boosting the growth rate of labour productivity.

The contribution of ICT-producing manufacturing to labour productivity growth rose substantially in the 1990s. This reflects in part the growing share of the ICT manufacturing sector in total manufacturing but also acceleration in technical change in the production of some ICT goods. ICT-producing manufacturing made the largest contributions to labour productivity growth in Ireland, Finland, Sweden and the US over 1996-2002. Its role was much more modest in Luxembourg, Spain, Italy and the Netherlands.

ICT-producing services contributed to labour productivity growth in the 1990s, although to a lesser extent than ICT-producing manufacturing. ICT-producing services boosted labour productivity growth in several countries such as Germany, Finland and Luxembourg. This rising contribution is partly due to an increase in productivity growth thanks to both the liberalisation of telecommunications and acceleration in technical change and partly due to the expansion of computer services in several economies.

Table III.3.1 Sectoral contribution to labour productivity growth in selected EU countries and the US, 1990-1995(1) and 1996-2002(2) (total economy, value added per person employed, contribution in percentage points)

	Total economy		ICT - producing manufacturing(3)		ICT - producing services(4)		ICT - using services(5)	
	1990-1995	1996-2002	1990-1995	1996-2002	1990-1995	1996-2002	1990-1995	1996-2002
Belgium	1.90	0.78	0.03	0.13	0.12	0.05	0.47	0.17
Denmark	1.99	1.45	0.09	0.09	0.27	0.13	0.18	0.37
Germany	2.11	1.38	0.17	0.09	0.18	0.46	0.17	0.12
Spain	1.22	0.28	0.14	0.01	0.09	0.16	-0.17	-0.03
France	1.13	1.00	0.20	0.21	0.02	0.14	0.01	-0.17
Ireland	2.39	3.76	0.43	0.89	0.10	0.28	0.15	0.73
Italy	2.83	0.56	0.09	0.02	0.12	0.20	0.88	0.14
Luxembourg	2.08	0.51	-0.03	-0.01	0.74	0.32	1.13	-0.20
Netherlands	0.63	0.77	0.10	0.03	0.09	0.17	0.25	0.28
Austria	2.32	1.73	0.12	0.11	0.15	0.13	0.59	0.51
Finland	2.65	2.02	0.20	0.82	0.13	0.36	0.10	0.22
Sweden	2.95	2.67	0.27	0.51	0.24	0.22	0.45	0.60
UK	2.20	1.08	0.19	0.12	0.18	0.24	0.37	0.85
US	1.12	1.74	0.33	0.45	0.14	0.16	0.24	1.29

Source: Pilat and Wölfl (2004), 'ICT production and ICT use: What role in aggregate productivity growh', in The economic impact of ICT, OECD, Paris. Key Figures 2005
Data: OECD
Notes: (1) DE : 1991-95; FR, IT : 1992-96.
(2) SE : 1996-98; ES : 1996-99; IE : 1996-2000; FR, UK, US : 1996-2001.
(3) ISIC Rev 3 30-33.
(4) ISIC Rev 3 64&72.
(5) ISIC Rev 3 71-74.

Increased productivity in the ICT-using sector

The impact of ICT is not limited to the ICT-producing sector but also extends to the ICT-using sector.

The use of ICT effectively enables firms to increase their market share, expand their product range, customise the services offered, respond better to demand, reduce transaction costs and inefficiency in the use of capital and labour and to establish networks. A more intensive use of ICT can thus help firms enhance their overall efficiency and performance. In this respect, an increase in labour productivity growth in the ICT-using sector may be caused not only by a greater use of capital but also by an increase in multifactor productivity.

Although there has been a dramatic increase in the contribution of the ICT-using sector to labour productivity growth in the US over the 1990s, this contribution has been quite limited in many EU countries such as Luxembourg, France, Spain, Germany and Italy.

Europe lags behind the US in experiencing an increase in labour productivity growth especially in ICT-using services. The performance of the US in the ICT-using services seems mainly due to a major acceleration in labour productivity and output growth in distribution (retail and wholesale trade) and financial services. Moreover, evidence shows that the surge in multifactor productivity in the second half of the past decade not only reflects acceleration in technical change in the production of ICT goods and services but also a major contribution of the ICT-using sector, primarily in retail trade and wholesale trade. According to Triplett and Bosworth[23], "IT in services industries accounted for 80 % of total IT contribution to US labour productivity growth between 1995 and 2001. As with labour productivity growth and multifactor productivity growth, the IT revolution in the US is a services industry story."

Although there are marked differences between EU countries, several factors can explain why the EU has not benefited from ICT as much as the US: high costs of ICT investments, regulatory environments (e.g. product market competition) and lower capacity of absorption and propensity to innovate of firms (e.g. organizational change and skills). Such factors are key determinants in influencing ICT diffusion[24]. In other words, ICT is not the only condition to increase productivity growth. ICT use requires complementary investments, in particular investment in intangible assets, and more generally, adequate framework conditions.

Table 3.3.2 Average annual growth of labour productivity per hour worked of ICT and non-ICT industries in EU-15 and the US

	1979-1995		1995-2002	
	EU-15	US	EU-15	US
Total Economy	2.3	1.2	1.8	2.5
ICT Producing Industries	6.8	7.2	8.6	9.3
ICT Producing Manufacturing	11.6	15.1	16.2	23.5
ICT Producing Services	4.4	2.4	5.9	2.7
ICT Using Industries	2.3	1.6	1.8	4.9
ICT Using Manufacturing	2.7	0.8	2	2.6
ICT Using Services	2	1.9	1.7	5.3
of which:				
Wholesale Trade	2.4	3.5	1.5	8.1
Retail Trade	1.7	2.4	1.5	7.1
Financial Services	1.9	1.5	2.3	5
ICT-intensive Business Services	0.8	-0.9	0.6	0.7
Non-ICT Industries	1.9	0.4	1.1	0.2
Non-ICT Manufacturing	3.2	2.3	2.1	1.2
Non-ICT Services	0.8	-0.3	0.5	0.2
Non-ICT Other	3.4	1.4	2.1	0.4

Source: Van Ark B. (2005), *Does the European Union need to revive productivity growth?*, Research Memorandum, GD-75, Groningen Growth and Development Centre. Key Figures 2005
Data: Groningen Growth and Development Centre

23. Triplett J. and B. Bosworth (2004), *Productivity in the US Services Sector: New Sources of Economic Growth*, Washington DC: Brooking Institution Press.

24. In addition, measurement problems in services and productivity may underestimate the impacts of ICT.

Annex I – Definitions and Sources

Symbols and abbreviations

Country codes

BE	Belgium	MT	Malta
CZ	Czech Republic	NL	Netherlands
DK	Denmark	AT	Austria
DE	Germany	PL	Poland
EE	Estonia	PT	Portugal
EL	Greece	SI	Slovenia
ES	Spain	SK	Slovakia
FR	France	FI	Finland
IE	Ireland	SE	Sweden
IT	Italy	UK	United Kingdom
CY	Cyprus	EU-25	European Union
LV	Latvia	US	United States
LT	Lithuania	JP	Japan
LU	Luxembourg	CN	China
HU	Hungary		

Other abbreviations

: 'not available'

- 'not applicable' or 'real zero' or 'zero by default'

General indicators

Gross domestic product (GDP)

Definition: Gross domestic product (GDP) data have been compiled in accordance with the European System of Accounts (ESA 1995).

Source: Eurostat.

Value Added

Definition: Value added is current gross value added measured at producer prices or at basic prices, depending on the valuation used in the national accounts. It represents the contribution of each industry to GDP.

Sources: Groningen Growth and Development Centre, OECD.

Small and medium-sized enterprises

Definition: For the purposes of this publication small and medium-sized enterprises (SMEs) are defined as enterprises having fewer than 250 employees. The Japanese definition of SMEs refers to enterprises with less than 300 employees.

Sources: Eurostat, OECD.

Purchasing Power Standards (PPS)

Definition: Financial aggregates are sometimes expressed in Purchasing Power Standards (PPS), rather than in ecu/euro based on exchange rates. PPS are based on comparisons of the prices of representative and comparable goods or services in different countries in different currencies on a specific date.The calculations on R&D investments in real terms are based on constant 2000 PPS.

Source: Eurostat

Part I – The Knowledge-based Economy in the Global Macro-economic Context

Labour Productivity

Definition: Labour productivity is defined as GDP (in PPS) per hour worked. According to the growth accounting methodology, labour productivity can be decomposed into capital deepening and multifactor productivity.

Source: Eurostat, DG ECFIN (Ameco Database).

Capital Deepening

Definition: Capital deepening is defined as the capital / labour ratio.

Source: DG ECFIN (Ameco Database); C. Denis, K. Mc Morrow, W. Röger and R. Veugelers (DG ECFIN), *The Lisbon Strategy and the EU's structural productivity problem* (European Economy Economic Papers nr 221, February 2005), European Commission, Brussels.

Multifactor Productivity

Definition: Multifactor Productivity (MFP) of Total Factor Productivity (TFP) is usually defined as the overall efficiency level of the production process. MFP is affected by factors such as labour quality/skill mix improvements; capital quality (vintage and asset composition); pure technological progress; sectoral reallocation effects; changes in capacity utilisation rates and measurements errors with respect to the contributions from physical capital / labour.

Source: DG ECFIN (Ameco Database); Denis, Mc Morrow, Röger and Veugelers (2005).

Composite indicators on the Knowledge-based economy

Definition: See Annex II.

Source: See Annex II.

Part II - Investment in the Knowledge-based Economy

Gross domestic expenditure on R&D

Definition: Gross domestic expenditure on R&D (GERD) is defined according to the OECD Frascati Manual definition. GERD can be broken down by four sectors of performance: (i) Business enterprise expenditure on R&D (BERD); (ii) Government intramural expenditure on R&D (GOVERD); (iii) Higher education expenditure on R&D (HERD); and (iv) Private non-profit expenditure on R&D (PNPRD). GERD can also be broken down by four sources of funding: (i) Business enterprise; (ii) Government; (iii) Other national sources; and (iv) Abroad.

Sources: Eurostat, OECD.

Rate of tax subsidies for 1 EUR of R&D

Definition: the 'rate of tax subsidies for 1 euro of R&D' compares the relative importance of R&D tax support across national tax jurisdictions.The relative generosity of R&D tax provisions has been calculated for large and small firms in the manufacturing sector of most OECD countries for the years 1995 and 2004.The 'rate of tax subsidies for 1 euro of R&D' is equal to one minus the so-called B-index.The value of the B-index is based on the before-tax income required to break even on one euro of R&D outlay and takes into account corporate income tax rates, R&D tax credits, special R&D allowances from taxable income, and depreciation of capital assets (machinery, equipment and buildings) used in R&D.

The B-index is the present value of before-tax income necessary to cover the initial cost of R&D investment and to pay corporate income taxes so that it becomes profitable to perform research activities. Algebraically, the B-index is equal to the after-tax cost of an expenditure of one USD on R&D divided by one minus the corporate income tax rate.

Source: OECD (see OECD, *Tax incentives for Research and Development: trends and issues,* 2003).

Venture capital investment

Definition: Venture capital in early stages of a company – i.e. seed and start-up stages – provides financing mainly for the initial business plan, research activities, product development and first marketing. It is part of total venture capital (= equity investments made for the launch, early development or expansion of business). Total venture capital itself is a part of total private equity capital for enterprises not quoted on a stock market.

Source: PriceWaterhouseCoopers (Moneytree Survey, Money for Growth 2004).

Researchers

Definition: Researchers (Research Scientists and Engineers, RSEs) include the occupational groups ISCO-2 (Professional Occupations) and ISCO-1237 (Research and Development Department Managers). See the "Frascati Manual" (OECD 2002a). The data for researchers are generally given in full-time equivalents (FTE). Only for female researchers as shares of all researchers are data used in headcount (HC).

Sources: Eurostat, OECD,WIS database.

Classification: ISCO: International Standard Classification of Occupation (version 1988).

S&E graduates

Definitions: Graduates are defined by the levels of education classified in ISCED 1997. In these key figures, graduates include all tertiary degrees (ISCED 5a and 5b) and PhDs (ISCED 6).The S&E fields of study are: life sciences (ISC42), physical sciences (ISC44), mathematics and statistics (ISC46), computing (ISC48), engineering and engineering trades (ISC52), manufacturing and processing (ISC54), architecture and building (ISC58).

Particularities: BE: data for the Flemish community exclude second qualifications (2000 to 2003). CY: Data exclude tertiary students graduating abroad. The fields of study in Cyprus are limited. EE: Data exclude master degrees (ISCED 5A). LU: Luxembourg does not have a complete university system; data refer only to ISCED 5B first degree. AT: ISCED level 5B (from 1998 to 2000) refers to previous years.

Source: Eurostat.

Classification: ISCED: International Standard Classification of Education (1997 version).

Part III – Performance of the Knowledge-based Economy

Scientific Publications

Definition: Publications are research articles, reviews, notes and letters that were published in referenced journals which are included in the SCI database of the Institute of Scientific Information (ISI). A full counting method was used at the country level, however for the EU-25 aggregate, double counts of multiple occurrences of EU Member States in the same record were excluded.

Co-publications are publications by two or more authors from two or more countries. Despite the possibility of several authors from one country, each country involved is counted only once.

Source: ISI, Science Citation Index; treatments and calculations: University Leiden, CWTS.

Triadic Patents

Definitions: 'Triadic' patents are the set of patented inventions for which protection has been sought at all three major patent offices (the European Patent Office – EPO, The US Patent and Trademark Office – USPTO and the Japanese Patent Office – JPO). The country of origin is defined as the country of the inventor. The advantage of triadic patents is that they can eliminate the 'home advantage effect'. They may also be associated with patents of a higher expected commercial value, since it is costly to file through three patent systems. However, it is also likely that they tend to reflect the patenting activity of larger companies who seek, and can afford, broader international protection.

Source: OECD based on data from EPO, USPTO and JPO.

Scientific specialisation

Definition: the relative scientific specialisation index (or relative activity index RAI) is calculated for 11 fields on the basis of publications from 2000-2003. The field 'Multidisciplinary' has been left out. RAI = a/b, where a = % of a country in all publications in a field and b = % of publications of that country compared to total publication output of all countries. Normalised score: RAI*=(RAI-1)/(RAI+1). Scores below -0.1 mean a significant under-specialisation in a given scientific field, scores between -0.1 and +0.1 are around field average and mean no significant (under-)specialisation, and scores above +0.1 mean a significant specialisation in a given field.

Source: ISI, Science Citation Index; treatments and calculations: University Leiden, CWTS. Calculation of broad fields: DG Research.

Technological specialisation

Definition: the relative technological specialisation index (or relative activity index RAI) is calculated for 17 manufacturing sectors on the basis of EPO patents from 1997-2000. RAI = a/b, where a = % of a country in all patents in a sector/technology field and b = % of patents of that country compared to total patent output of all countries. Normalised score: RAI*=(RAI-1)/(RAI+1). Scores below -0.1 mean a significant under-specialisation in a given scientific field, scores between -0.1 and +0.1 are around field average and mean no significant (under-)specialisation, and scores above +0.1 mean a significant specialisation in a given field. The data were classified by earliest priority date and country of residence of the inventor.

Source: DG Research, based on OECD data.

High-tech trade

Definition: Indicators on high-tech trade refer here to exports by the high-tech manufacturing sectors (production approach).

Sources: Eurostat (Comext), UN (Comtrade).

High-tech and medium high-tech industries

Definition: High-tech and medium high-tech industries are defined by their average R&D intensity (i.e. R&D expenditure as percentage of value added). According to the Eurostat definition, high-tech and medium high-tech industries consist of the following manufacturing sectors: manufacture of chemicals and chemical products, manufacture of machinery, motor vehicles and of other transport equipment, mechanical and automotive engineering, machinery and transport, manufacture of office machinery, electrical machinery, radio, television communication equipment, medical, precision and optical instruments (i.e. NACE 24, 29, 30-33, 34, 35 – 352, 353, 354 and 355).

Sources: Eurostat (SBS, CLFS, National Accounts) and OECD (Science, Technology and Industry Scoreboard).

Classification: NACE Rev. 1. For Eurostat, ISIC, Rev. 3 for OECD

Annex II – Methodological Note on Composite Indicators

The use of composite indicators to assess progress towards the knowledge-based economy is an emerging and pioneering field. Composite indicators have already been successfully used at both national and international level in a number of different policy fields where it is necessary to summarise complex multidimensional phenomena[1].

In the framework of the Commission's Structural Indicators exercise[2] it was decided that it would be useful for the Commission services to investigate and develop composite indicators of the knowledge economy. A number of Commission services have been involved and consulted during the development work including DG Education and Culture, Eurostat, DG Information Society and DG Enterprise. External technical assistance was provided by Anthony Arundel and Catalina Bordoy of MERIT. The Applied Statistics Group of the Joint Research Centre also contributed significantly to reviewing different approaches, testing the sensitivity and robustness of the chosen method, as well as performing uncertainty analyses to assess the reliability of imputations in the case of missing data[3].

This 2005 edition of Key Figures includes composite indicators for the EU-15 as well as the US and JP, up to 2002.

What do the composite indicators tell us?

The composite indicators used here are a weighted average of a number of components or base indicators (see below). They reveal several things:

1) For any given year, they show the position of the country concerned (as the mean of the various base indicators) compared with its partners: if one country's composite indicator (index) is higher than another's, the country with the higher index is in a better position.

2) If we follow one particular indicator for several years, it shows us how the country is progressing over time. If the index is higher in year n+1 than it was in year n, the country's performance (or capacity) has improved over that period.

3) The value of a composite indicator during year n shows the position of the country compared with the European average in the reference year (1995 in this case):

- a positive value means that the position of the country in year n is above the European average for 1995;
- a negative value means that the position of the country in year n is below the European average for 1995.

1 For example: · United Nations, *Human Development Report*, 2001 [Human Development Index, Technology Achievement Index]. · International Institute for Management Development, *The World Competitiveness Yearbook (2000 and 2001)*, Lausanne. · Nistep, *Composite Indicators: International Comparison of Overall Strengths in Science and Technology»*, Report No 37, Science and Technology Indicators 1994, A Systematic Analysis of Science and Technology Activities in Japan, January 1995. · World Economic Forum, *Pilot Environmental Performance Index,* Yale Center for Environmental Law and Policy, 2002. · Alan L. Porter, J. David Roessner, Xiao-Yin Jin and Nils C. Newman, *Changes in National Technological Competitiveness: 1990-93-96-99,* (available on Internet). · Michael E. Porter and Scott Stern, *The New Challenge to America's Prosperity: Findings from the Innovation Index, Council of Competitiveness,* Washington DC, 1999. · Progressive Policy Institute, *The State New Economy Index*, www.neweconomyindex.org/states, 2000.

2. Communication from the Commission: Structural indicators, COM(2001) 619 final, Brussels, 30 October 2001.

3. *State-of-the-art Report on Current Methodologies and Practices for Composite Indicator Development*, Joint Research Centre - Applied Statistics Group, Ispra, June 2002 (www.jrc.cec.eu.int/uasa/prj-comp-ind.asp). *First workshop on Composite Indicators of Country Performance,* Ispra, May 2003. (www.jrc.cec.eu.int/uasa/evt-OECD-JRC.asp). The link contains substantial material on composite indicators

Component indicators and their weights

The composite indicators are calculated using the component indicators and weights[4] listed in Tables AII-1 and AII-2.

The technique adopted here is to base the weights given to component indicators on a conceptual understanding of the phenomenon that we are trying to measure. Each composite indicator contains a number of 'conceptual groups'. These conceptual groups may contain one indicator or several. The different conceptual groups are given equal weightings, while within each group the components indicators are also accorded an equal weight[5].

Table AII-1 Component indicators and weightings for the composite indicator on investment in the knowledge-based economy

Component indicators	Conceptual group	Weight
GERD per capita	Knowledge creation	2/24
Researchers per capita	Knowledge creation	2/24
New S&T PhDs per capita	Knowledge creation	4/24
Education expenditure per capita	Knowledge creation and Knowledge diffusion	4/24 + 3/24
Life-long learning	Knowledge diffusion: human capital	3/24
E-government	Knowledge diffusion: information infrastructure	3/24
Gross fixed capital formation (excluding construction)	Knowledge diffusion: new embedded technology	3/24

Source: DG Research Key Figures 2005

Table AII-2 Component indicators and weightings for the composite indicator on performance in the knowledge-based economy

Component indicators	Conceptual group	Weight
GDP per hour worked	Productivity	4/16
European and US patents per capita	S&T performance	2/16
Scientific publications per capita	S&T performance	2/16
E-commerce	Output of the information infrastructure	4/16
Schooling success rate	Effectiveness of the education system	4/16

Source: DG Research Key Figures 2005

For example, the investment composite indicator contains two conceptual groups: knowledge creation and knowledge diffusion, both of which receive an overall weight of 12/24 (see table above), the component indicator "total education spending" contributing to both groups (4/24 to the creation group and 3/24 to the diffusion group). The performance composite indicator has four 'conceptual groups' which are equally weighted.

Whilst this system may not correspond to the theoretically ideal set of weights that we would choose if we knew precisely the contribution of each component indicator to explaining the knowledge-based economy (which is impossible to estimate whatever method we use), it has the advantage of being clear, transparent and conceptually coherent.

4. These are the weights used for the calculation of the positions of EU Member States. The weights used for the growth rates and for comparisons with the US and Japan have had to be slightly re-adjusted owing to non-availability of some variables or time series (see section below on data availability).

5. With the exception of R&D expenditure and numbers of researchers which are given the weighting of one instead of two component indicators because of the close link between these two variables (most of R&D is researchers' salaries).

Calculation method

All methods of calculating a composite indicator must transform indicators that are measured in different units into the same unit. For example, indicators measured in terms of euro, percentages, and per capita must be transformed into a single measurement unit. The method used here for the composite indicators of the knowledge-based economy is to calculate standardised units by re-scaling values in terms of their standard deviations. If x^t_{ji} is the value of the component indicator for country i at time t, then for each component indicator one calculates the standardised value: $y^t_{ji} = \frac{x^t_{ji}}{\sigma^0_j}$

where σ^0_j the standard deviation, of the component indicator j at time 0. (In the calculations of the composite indicators presented here the base year 0 has been chosen as 1997.)

The composite indicator I^t_i of a country i is then calculated as the sum of these standardised values y^t_{ji} weighted by the coefficients q_j (whose sum is equal to “1”, so that the composite indicator is commensurable with its components), i.e. $I^t_i = \sum_{j=1}^{n} q_j y^t_{ji}$

The annual average growth rate of the composite indicator between 0 and t is $r_i^{0,t} = \left(\frac{I^t_i}{I^0_i}\right)^{1/t} - 1$

Data availability, sensitivity and robustness analysis

The availability of complete time series for all countries and component indicators is very important for the calculation of composite indicators, since gaps in data are compounded when aggregating across many variables, countries and years. An important criterion for the selection of the component indicators (along with quality and comparability) was therefore the completeness of the datasets.

Nevertheless, comparable data for some component variables (e-commerce, e-government, life-long learning, schooling success rate) were not always available for the US and Japan as well as for some new Member States. The composite indicators calculated for comparisons with these countries exclude these components and use re-adjusted weights. Luxembourg is not included in the composite indicator on investment (no data for most of the base indicators) nor in the composite indicator on performance (too sensitive to productivity).

Certain base indicators are only available for one year (no time series): in such case growth rates are calculated excluding these indicators, with the weights re-adjusted accordingly.

Some data are missing for a few countries. Where statistically appropriate, a regression model (best fit scenario) has been used to fill in data gaps. Monte Carlo-based uncertainty analysis has been carried out to validate the robustness of the resulting composite indicator to forecasted values. In total, forecasted or interpolated values represent 13 % of the overall matrix.

The sensitivity of the composite indicator to the omission of one base indicator at a time has been tested in terms of change in countries ranking, and this has been taken into account in the analyses.

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Key Figures 2005 provides a set of indicators which help us to take stock of Europe's position in science, technology and the knowledge economy. The report contains graphs, tables and comparative analyses of the European Union's performance in relation to its main partners.

Part I of the report reviews the most important aspects of EU investment and performance in the knowledge-based economy.

Part II of the report examines EU investment in the knowledge-based economy through indicators of R&D expenditure, human resources in science and technology, and higher education.

Part III of the report deals with the performance of the EU's research and innovation systems examining indicators such as scientific publications and patents as well as high-tech trade, productivity and value added at the sector level.

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